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MOON BASE

*technical and
psychological aspects*

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On Men and Materials

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JOHN F. RIDER PUBLISHER, INC., NEW YORK

London: CHAPMAN & HALL, LIMITED



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Library of Congress Catalog Card No. 60-8975

Printed in the United States of America

PREFACE

All media of entertainment such as TV, radio, science fiction, cartoons, and comic strips are utilizing the human interest of space flight. Special attention is given to the moon due to its relative proximity to earth and the rapid technological advancements which are bringing this human dream closer to reality. These and other semi-scientific popularized approaches to the problems involved are, in many cases, distorting the facts and are far from educating the American public. Yet the "space mindedness" and the proper perspective of even the man in the street is essential to our national effort for space supremacy which, in turn, is not only important for the enrichment of human knowledge, but mandatory for our democratic survival. Therefore, I have attempted to present certain aspects of astronautics, with special reference to a lunar base, at a high technical level. I did not change the technical terms and expressions because I feel that, by overpopularizing scientific communications, the reader is unduly underestimated, and an opportunity is lost for technical education. Technical terms are important for communication in their respective fields, and there is no reason why they should be kept out of the vocabulary of the layman. To familiarize the reader with some of the specific or unique terms there is a glossary provided on pages 71 and 72.

PREFACE

The technical description of the Moon Base prototype is very sketchy. The reason is that the aim of this book is to show only the main problem areas in the construction of the Moon Base.

In the treatment of the crew selection, in the psychological and socio-psychological aspects, the problem of mixed sexes has been analyzed. Because it will be a long, long time before teenagers or buxom movie stars will travel in space, problems of sex in astronautics are of minor importance. It is most unfortunate that some reporters feel that, for the greater glory of journalism, they must spice their stories with aphrodisiacs which they call "human interest." I hope that, should this modest book be honored by the attention of reviewers, it will be done in good taste and in such a way as to promote the aim of this book: disseminating scientific knowledge.

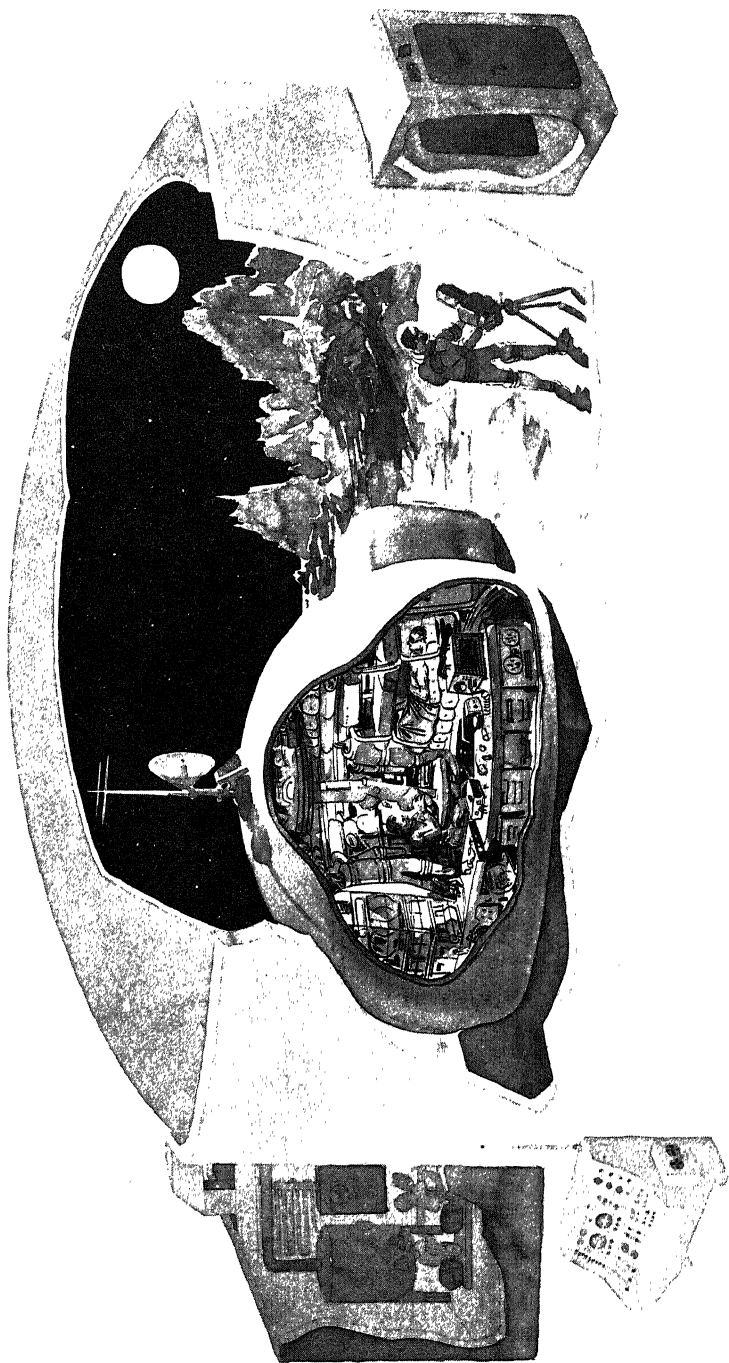
I acknowledge gratefully the aid of Radiation Incorporated in the production of this book and appreciate highly the assistance of Mr. W. Castle, Mr. A. Harkins, and Dr. Thomas Gordon in the writing, reading, and illustrating of this material.

January 1960
Orlando, Florida

T. C. HELVEY

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Moon Base prototype and lunar environment simulator.

Part I TECHNICAL FACTORS

Section 1

INTRODUCTION

Rapid advancement in the technology of space frames, propulsion, and guidance systems will bring about in the U.S., by the year 1961, a payload capability which may surpass 20,000 pounds. The Russian space technology could probably achieve this even sooner.

This indicates that the time is nearer than anticipated when space vehicles can carry a group of humans with all the necessary equipment to operate in a space-equivalent environment for a considerable length of time and then return them to earth.

The race for the moon is enhanced by its high military value. Although much is said about the peaceful utilization of space, including the moon, strategically located bases on the moon are of major military significance. Some of the areas for strategic application of Moon Bases are communication jamming, surveillance, establishment of launching sites for satellites and warheads, anti-satellite operations, and specific communications

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of military significance, etc. In the near future, the moon will have primarily strategic significance, but at a later date, when space itself may become the theater for combat action, a Moon Base will have tactical values.

As long as only unmanned satellites or space vehicles are at stake, we can afford to lag behind the Russians because this means only a political or prestige loss, but as soon as lunar military bases are established by the Russians, it may be impossible to remedy the matter and catch up with them short of a shooting war. It is quite obvious that, should the Russians be able to establish a few bases on strategically important points of the moon, they will consider this environment as part of the Russian territory. The value to the U. S. of having "squatter's rights" on the moon appears enormous, because not much political argument would be necessary to prevent us from landing on the moon, and it is unlikely that we would be able to deter such a hostile action unless we achieve a major break-through in our weapon systems. It is equally unlikely that the Russians would willingly give us or share such unique advantages in the military and political fields as are provided by significantly located bases on the moon unless international attitudes and tension are drastically modified. Even if an arrangement should come about which would permit us to build bases on the moon, the strategically important possessions will be already occupied by those who came first.

Beside the military aspects there are enormous scientific and economic potentials to the country which is in possession of the moon. Sciences — like astronomy, astrobiology, astronautics, etc. — will receive an emphasis beyond imagination. This indicates the values of the Moon Base for peacetime applications.

In spite of the fact that space medicine and man-machine systems for manned space vehicles have been significantly advanced in the last years, much time-consuming research and investigation has to be done before the first crew can be safely dispatched to the moon. Consequently, the establishment of Moon Base prototypes and lunar environment simulators becomes extremely urgent.

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In the following, two aspects will be treated with respect to the Moon Base concept:

1. The technical description of some of the features of a Moon Base prototype and lunar environment simulator
2. The psychological analysis of the smallest operational crew composition

The philosophy in the design of a Moon Base prototype would be to provide, with the highest possible fidelity, the multiple stress profile of the operation on the moon. This requires that all parameters which are known according to the present state of the art be concerned. The use of the simulator would be to provide all reproducible stresses of the lunar environment.

The objectives of such a system are to provide a capability for the operation of military or research teams on the moon's surface which could operate there for the duration of a minimum trip and also for as long as two years. Furthermore, the possibility of an expansion into the Mars and/or Venus environment should be incorporated in the design.

Such a system would permit extensive studies for system analysis and reliability experience of the integrated components and subsystems under true operational conditions.

The severe environmental conditions of a Moon Base and the remoteness of the operation require the highest reliability of equipment and personnel. This demands an entirely new dimension in the construction of man-machine systems which can fulfill the requirements of safety.

It would seem at first that the task should be approached by the design of a primitive system. Refinements should be developed as need appears for more sophistication during actual operation. This approach, although conventional and orthodox, cannot be applied in this case because of the severe competition from abroad. Instead of the usual evolution, we should embark on a rather revolutionary development of the task by aiming at the ultimate goal, the operational Moon Base.

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The only similarities between space capsules and a Moon Base are in some of the equipment for the maintenance of earth-equivalent environment. Even here, because of the great difference in the time element, the approach must be different, although some basic principles might coincide. For the next decade, only cis-lunar and lunar missions are expected with a relatively short duration of less than six days. The Moon Base prototype is designed and should be developed for missions having durations up to two years. It is obvious that such studies will develop techniques for radically different translunar trips with many months or years duration.

Section 2

SIMULATOR OF APPROXIMATE LUNAR ENVIRONMENT

The philosophy in the design of the lunar environment simulator is to simulate with the highest possible fidelity the multiple stress profile of the moon surface environment. This requires that all known parameters, according to the present state of the art, be considered. The following factors should be incorporated in such a design:

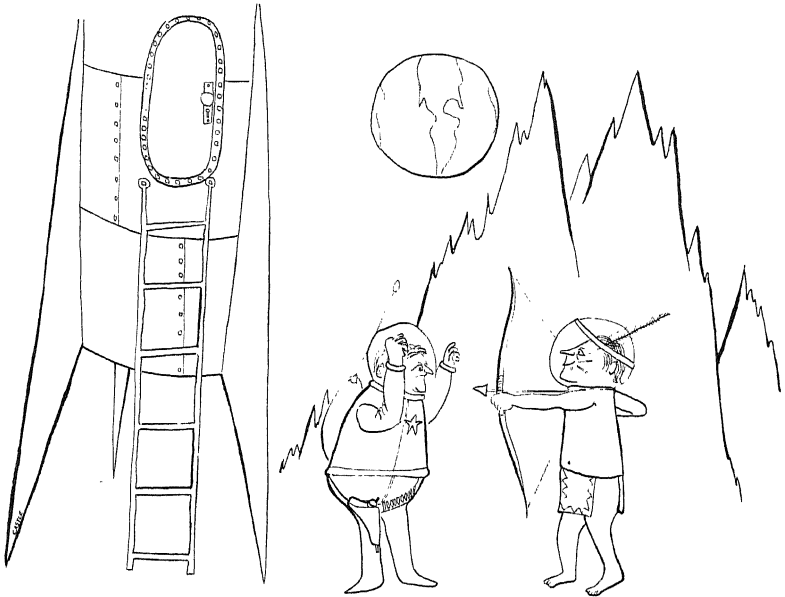
1. Altitude
2. Temperature extremes
3. Illumination
4. 1/6-g gravity

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5. Landscape and surface texture
6. Meteorites
7. Cosmic radiation

SIMULATION OF ALTITUDE

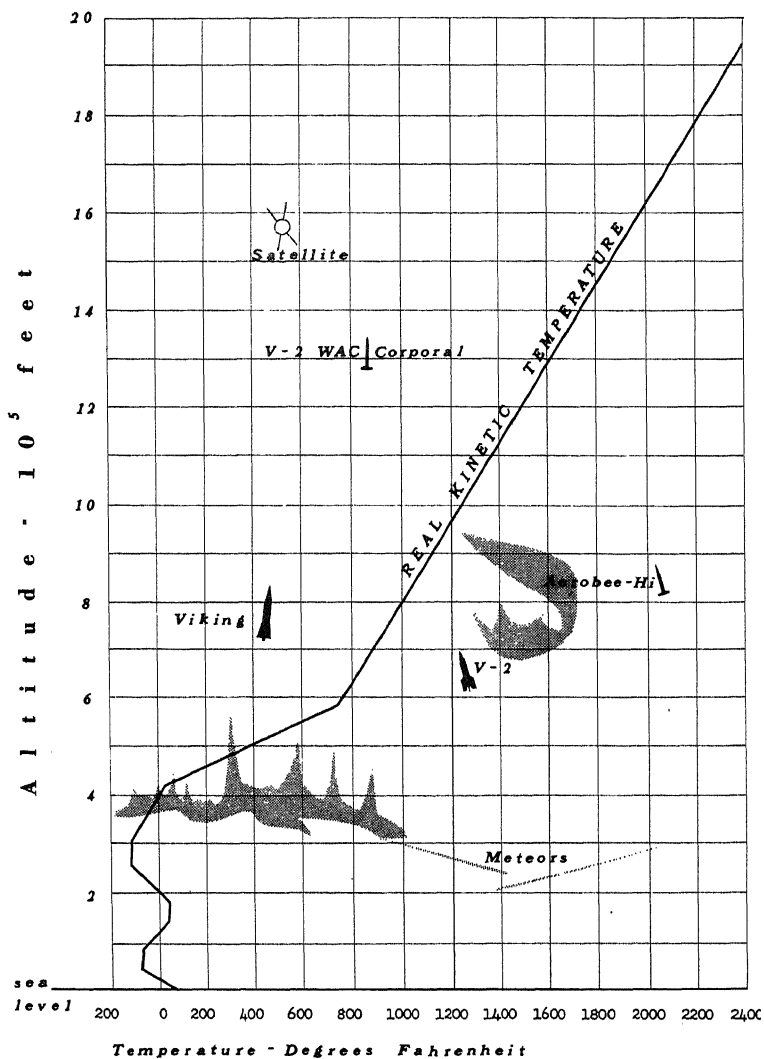
The environmental chamber will be a 70-ft-diameter spheroid with an airlock. The pressure wall is designed for 15 lb/in² but the simulated altitude will not exceed 35,000 ft. The reason for this low vacuum is safety. If either the Moon Base



shell or a space suit should be ruptured, and thus explosive decompression occur, the lives would not be in danger. In the base shell, a pressure sensor would open a large, load-free magnetic valve which breaks the vacuum in the environmental chamber and shuts off the pump, but the relief is not instantaneous. In the case of malfunctioning of a space suit, the person can be rescued

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ALTITUDE CHART



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by the monitor stationed in the base. The fact is that, under true moon conditions, this would probably be impossible because of the boiling of body fluids, but the suit itself should be previously subjected to rigorous engineering testing. The altitude is achieved by two 25-hp vacuum pumps. One of these pumps would have satisfactory capacity to achieve and maintain the required partial vacuum, and the second would be a standby unit which could be used also for speeding up initial evacuation.

TEMPERATURE

Low Temperature

The temperature in the environmental chamber will be kept at -20°F . Again, the reason for this moderate stress is that all equipment can be functionally tested at -200°F in a small chamber, but maintenance of that temperature in such a system as the simulator would not be feasible economically. The indicated temperature is low enough to force the crew to wear their space suits every time they leave the base. The study of the operation of the crew in space suits for prolonged periods of time is one of the prime objectives of the simulator. The experience gathered from the space-suit equipment is valuable, but only incidental.

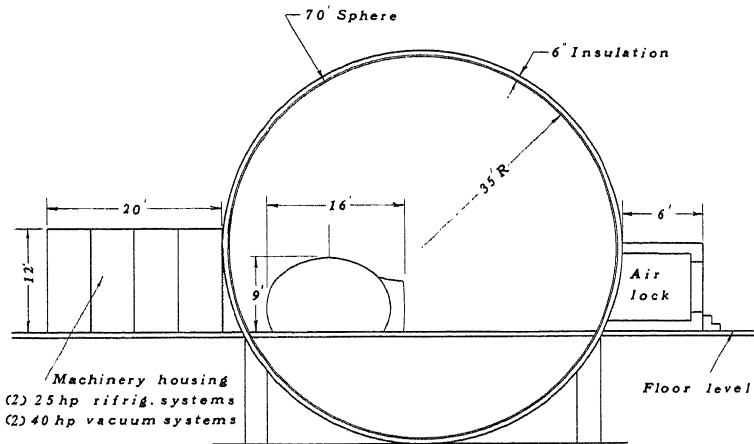
The refrigeration is brought about with two 25-hp units with 15-kw heat dissipation capability. Here again, one unit is kept as a standby, because the time of individual test runs does not tolerate possible repair downtime. The insulation of the spheroid chamber is an external 6-inch cork-plaster shell, which is the most economical and will serve the purpose.

High Temperature

Owing to lack of atmosphere on the moon, only radiative heat is encountered. Therefore the chamber will be kept essentially at -20°F , and a solar simulator will deliver, at intervals representing the lunar day, about $2 \text{ cal/cm}^2/\text{sec}$ radiant heat.

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Because of the burden on the refrigeration system, this degree of radiation should be maintained only if crew members are outside the base. There are, at present, no electric bulbs developed which would truly simulate sun radiation. The closest one is a battery of GE quartz tubes with 1-kw capacity, combined with a number of carbon arcs. This simulator will be placed outside



the chamber and reflected into the chamber by mirrors. The mirrors are mobile and will cover a certain part of the path of the "sun." There are also adequate windows provided for good simulation. This problem of insolation requires, however, further study and development.

ILLUMINATION

During moon-night, the earth simulator will provide the illumination expected on the moon surfaces. This will amount to about 2.5–3 millilambert if the earth is full. While the "sun" is up, the glare of the lunar day, reflected from the moon surface, will require adjustable polarized goggles.

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LOW GRAVITY

It is beyond doubt that the crew members will have to be acclimatized to the low lunar gravity. It can be anticipated that the 1/6-g conditions will suffice for the gravity-dependent physiological functions. Primarily, the adjustment will be necessary in the psychophysical field. Muscle coordination, and kinesiology in general, will require special training for lunar work. This is a good place to draw attention to the expected fact that the findings of ergology, the science of human work output, will have to be corrected for lunar conditions. Items — such as human transfer functions, reaction time — will be different on the moon, and man-machine systems will have to be designed accordingly.

It is probable that lunar missions, after the Moon Base is operational and reliable, will be long lasting because of the economic considerations. Therefore, problems of rehabilitation of crew members after their return will bear importance. The degree of muscular dystrophy after exposure to twelve months at 1/6 gravity is impossible to estimate. It seems very desirable to simulate lunar gravity conditions in the moon base prototype as far as possible. The simulation of subgravity on earth in a static system must be, as it is *a priori* evident, very incomplete. The only justification for its application is that it coincides with another effort which is mandatory for payload considerations. This approach will be to reduce the weight of all familiar tools, equipment, and commodities to the utmost minimum. This will familiarize the crew members with the type of sensation they will encounter on the moon, and thus the time of their adjustment can be substantially reduced. Because anatomical features cannot be reduced in weight, the drastic reduction of exercise could compensate somewhat for it.

LANDSCAPE AND SURFACE TEXTURE

For the enhancement of the impression of trueness and the reinforcement of the feel of remoteness, a most convincing replica of the moon landscape must be provided in the interior of

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the environmental chamber. This attempt is greatly facilitated by the fact that tactile sensation is excluded at all times by the heavy gloves. In constructing the landscape, one must bear in mind, however, that the mind subconsciously can obtain considerable information by evaluating sensations as they occur by hitting, kicking, or pressing objects, or by bumping into obstacles.

It is also very important that the earth and at least some of the planets and stars as they appear on the sky not be stationary, but that they simulate movement. Due to this feature, many astronomical tasks of the lunar research operator will be more realistic. Because the true appearance of the sun cannot be simulated, no means for its study should be provided. The anticipated exciting solar research must wait until man has established his first moon observatory or until the satellite-borne telescope systems are perfected.

The realism of a simulated lunar environment can be further enhanced by applying a slightly distorting film on the visor of the space suit. This would not hinder any operation, even reading, and the visual perceptive mechanism would soon adjust to the unusual information. The advantage would be that small imperfections in the simulation, which cannot be avoided, would not impress continuously on the crew member and thus counteract our indoctrinating efforts for simulating lunar environment.

METEORITES

The simulation of the meteoritic environmental parameter involves a great number of psychological and technical problems. The crew will be told that hidden in the chamber are some spring loaded guns, which have different calibers and will be discharged randomly in time, but which will have certain probability distribution concerning their direction and size. Thus the crew will expect meteor impacts without knowing their size and time, but may develop favorable distribution of vital equipment in the base with minimum hit probability. It is important to learn about the anxiety value of such a situation and the adaptation pattern for various individuals. The plan calls for shots

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which will penetrate the shell of the base, and some will, by purpose, damage vital equipment. This is to study the crew efficiency in repair work and the limits of reparability of the equipment. Small lead pellets will perforate space suits for the same purpose, but, of course, not while they are worn by the crew.

Concerning meteoric damage, it should be mentioned that only perforations between 2 and 200 mm² should be taken into consideration. On the one hand, space debris smaller than about 2 mm will be eliminated by a double bumper which will be placed around the plastic hull of the base on the moon. On the other hand, the energies with which such small pellets can be hurled against the Moon Base prototype in the simulator will be inadequate to cause any significant damage. It is estimated that, through perforations up to 2 cm², the air pressure in the Moon Base will drop to 500 millibars within the limit of the required time for repair by the crew before they lose consciousness, arbitrarily setting this time for 60 seconds. The direct hits of large meteors on the moon are so infrequent that they have not been taken into consideration. Furthermore, the probable damage to life or vital equipment caused by a large meteor would be such that the mission should have to be considered lost.

COSMIC RADIATION

It is assumed that solar batteries will be inadequate for the primary power source of the base because of their unfavorable power-to-weight ratio and bulkiness. For motive power and heat supply, a small nuclear reactor will be necessary. This feature and the primary and secondary cosmic radiation will bring about an unavoidable exposure to radiation which, of course, must be measured and monitored by the crew. Since it is inconceivable to expose the crew members in a training device or in the Moon Base prototype to ionizing radiation, their measuring equipment will be biased to simulate various intensities. The crew will be unaware of this and will have no means of verification. They will assume that the experiments cannot, and will not, be carried into the danger zone, and the programing will take this

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into consideration. But dose rates slightly above the permissible level for certain intervals are thinkable, and their psychological effects on behavior and performance can be studied. Ultraviolet radiation will not cause problems on the moon as far as the crew is concerned, and therefore this environmental parameter should not be simulated. The equipment and materials which will be exposed to the strong ultraviolet radiation on the moon surface must withstand its effects.*

A certain amount of radiation shielding may be necessary on the moon surface for tolerable long-term lunar missions. If the surface material on the moon does not contain high-atomic-number elements, subsurface location of actual Moon Bases would be of little value from the point of radiation shielding. Thus such materials must be carried from the earth. Some personal protection can be achieved by the adapted variation of our protective suit for nuclear-powered vehicles.

The necessity for protective suiting against radiation has been manifest since the earliest days of nuclear technology. A number of attempts to design adequate suiting have failed owing to the fact that gamma-ray attenuation is proportional to the atomic weight of the shield, and suits so designed become far too heavy to be borne by a human.

The problem of such a suit became critical as nuclear warheads were developed and protective devices were needed for infantrymen. Again, excessive weight defeated success.

A new impetus was added to the search when nuclear-powered airplanes got on the drawing boards, and crew protection came sharply into focus.

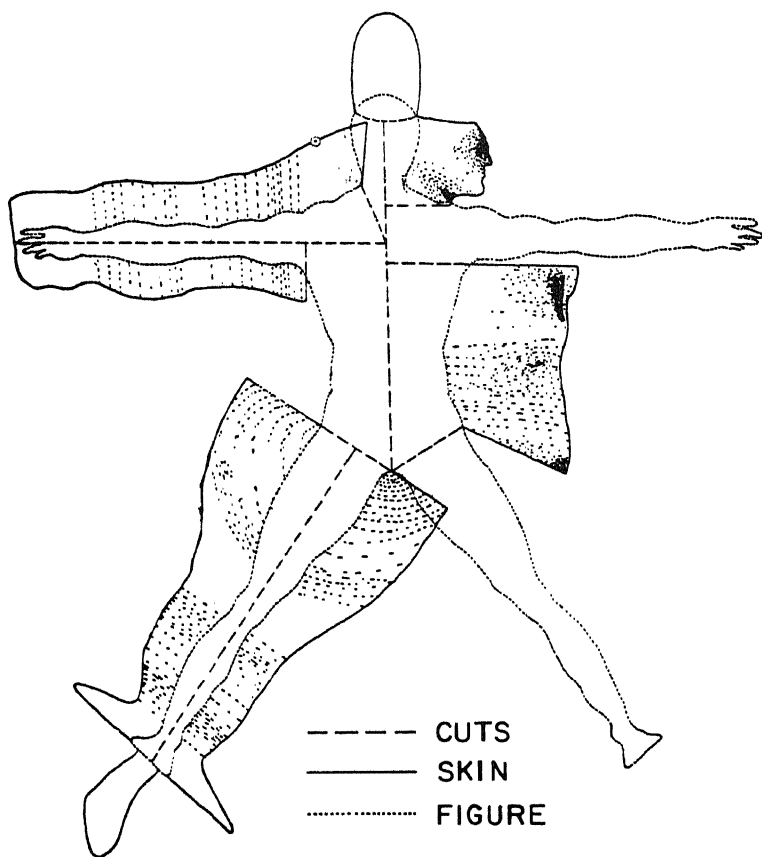
The question of radiation protection for the crew is a complex and difficult one. In stationary radiation sources, either land or water based, the shield weight is not important. However, in airborne vehicles the weight factor is highly critical. In the Moon Base, the crew could receive an intolerable radiation dose, especially on long missions.

* Helvey, T. C., *Effects of Nuclear Radiation on Men and Materials*, New York: John F. Rider Publisher, Inc., 1959.

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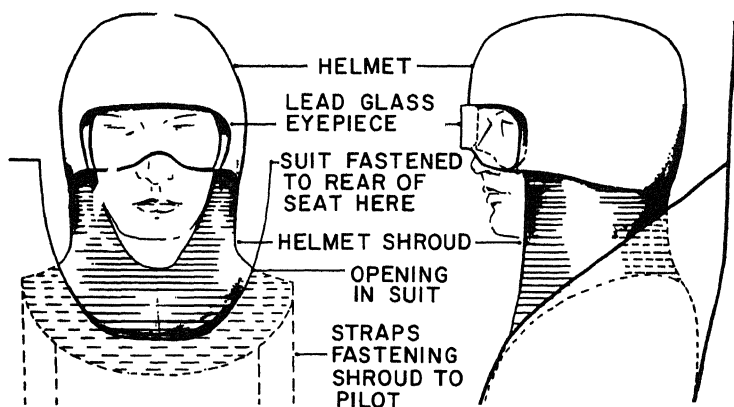
Sensitivity of the human organism to radiation is still a highly controversial scientific subject. It is known that various parts and organs of the human body have different degrees of sensitivity and that tolerance limits must be set to the most sensitive organs. This sensitivity and the unknown danger of genetic effects require a very conservative maximum permissible dose rate.

Using the relative sensitivities of organs as criteria, it was possible to construct the approximate isodose pattern of the



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human body (See Figure). The construction was based on the assumption that a person will receive a uniform diffuse and mono-energetic gamma-radiation dose. Such a pattern takes into consideration, to a certain extent, the attenuation of the radiation by parts of the human body. Accordingly, lead platelets were placed in the fabric of a suit. The density of these platelets per unit area varied according to the relative sensitivity of the body surface. The aim was to shield the more sensitive parts of the body to obtain a uniform effect over the entire body surface. This design pattern increases the permissible ambient gamma flux within the crew compartment by a factor of about 5 or more.



The grid effect, another phenomenon that adds to the effectiveness of the suit, can also be applied. It has been found that — weight for weight — the smaller the skin surface covered by a grid pattern of lead pellets or strips, the greater the protection. The application of this factor is, of course, valid only within certain limits. Nevertheless, within these limits, the protective action of living tissues and the dividedness of the lead shield are in direct relation. This phenomenon is explained by the diffusion of molecules with free sulphhydryl radicals from the shielded areas into the exposed tissue areas. This grid pattern provides an added gamma-ray protection up to approximately 30%.

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The protective suit is made of glass fibers of the lead silicate type, with about 82% PbO and has the gamma attenuation of steel. The suit weighs about 150 lb on earth — 25 lb on the moon.

Section 3

PLASTIC LUNAR CREW SHELL

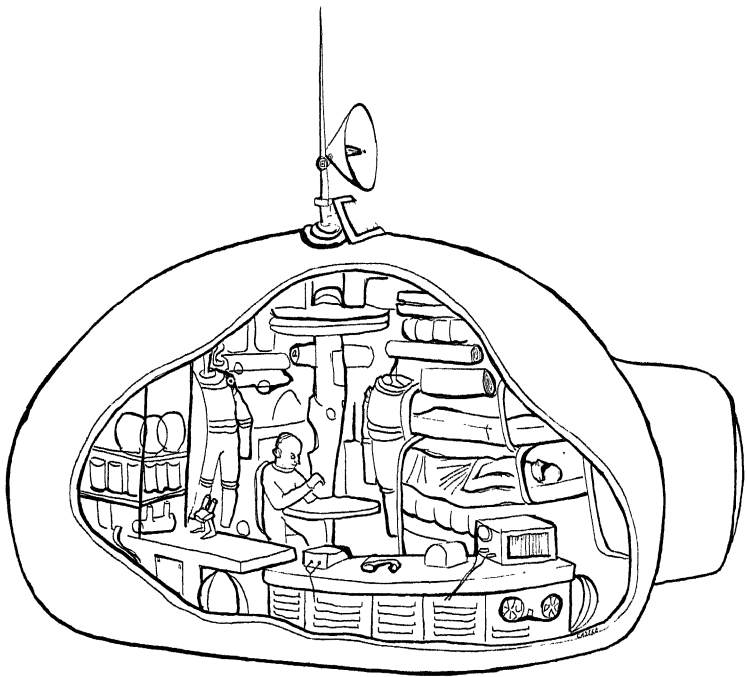
Preliminary studies for the material from which the lunar base should be built have already been undertaken. These studies were successful although the material used has not been tested to withstand prolonged lunar environment and we are certain that these preliminary studies would not be satisfactory under the mentioned conditions. This study of the appropriate material should be done by persons who have experience in the effects of extreme temperatures, insolation, and nuclear radiation on high polymers. For weight considerations, transportability, and feasibility for erection on the moon surface, a plastic shell is proposed. This shell is composed of a double layer of an appropriate polymer sheet which can be inflated. After inflation the 6-inch space between the two sheets should be filled with plastic foam which is generated in this interspace after the inflation of the shell. Such a foam will harden after some time and will thus form an excellent thermal and pressure barrier. The solidification of the polymer at space temperature can be achieved with an appropriate catalyst.

Such a shell must be subjected to rigorous engineering testing, and we have already designed the required test parameters which would be applicable.

Section 4

**EQUIPMENT FOR THE MAINTENANCE OF THE
EARTH ENVIRONMENT WITHIN THE BASE**

The complete and detailed coverage of this section should be partially the task of a separate study. In the following, only a few of the parameters should be discussed to demonstrate the



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approach to some basic problems. The technical solutions mentioned here may be strongly altered in the special study.

ARTIFICIAL ATMOSPHERE

In the establishment of the artificial atmosphere for the Moon Base, the following parameters should be taken into consideration:

1. Oxygen supply and measurement of its partial pressure
2. Carbon dioxide elimination
3. The inert gas and the measurement of the total gas pressure
4. Humidity
5. Removal of toxic or obnoxious constituents of the air
6. Air movement within the base

Oxygen Production

The present state of the art indicates that the best solution for this problem is photosynthesis. As long as the only missing link in the dynamics of photosynthesis has not been discovered, natural photosynthesis will have to be used. There are a number of papers written on the subject, and research is going on at various institutions to discover the most efficient phyto-organism for photosynthesis. In spite of the fact that the human respiratory quotient is not exactly 1, it is probable that the metabolism of the used plant material can be directed so that it would be useful without any supplementary oxygen which would have to be carried in a vehicle. At present, only unicellular algae are recommended. These organisms have the shortcoming that, for various biological and technical reasons, the concentration of the nutrient cannot be very high. The algae and the nutrient solution, including the plastic containers, the liquid and air pumps, as well as reserve stock culture and spare parts, cannot be built below 800 lb for a three-man crew. This figure does not include the light source because it is assumed that direct sunlight will be available. Some time ago, I carried out some

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exploratory experiments concerning enhancement of photosynthetic activity of chloroplasts induced by radioactive isotopes. These experiments could not be carried to an end, and my results are inconclusive. If, at a later date, this experiment should be completed and should show positive results, it would indicate that soft x-rays could be utilized for photosynthesis. Since this approach must be considered impractical, let us survey the problem from a different angle. There is a great disagreement between German and American schools on the mechanism of the quantum conversion in the first steps of photosynthesis. According to the generally accepted theory, the source of energy for photosynthesis is derived from photons which bring about the fission of water molecules and create hydrogen radicals. These radicals are absorbed by an unknown enzyme system — the so-called hydrogen acceptor — and transferred to a quantum converter of unknown chemical composition, which delivers them into a biochemical train of photosynthetic events. It is thinkable that the acceptor is not shielded by specific molecular bond configurations and will pick up hydrogen radicals whenever they occur within the sphere of polar attraction. Thus the energy-carrying radical can be generated not only by the photolysis, but also by the radiolysis of water. If this is the case, it becomes very probable that reduction of carbon dioxide can occur in the absence of light and that the hydrogen for photoreduction processes can be obtained also from sources other than water, such as hydrogen sulfide or molecular hydrogen. These would indicate the accessibility and high degree of polarization of the hydrogen acceptor. Encouragement for this theory was given by a recent report, according to which a biocatalyst — 2, 4-dihydroxyphenylalanine — is converted into melanin by x-rays, as well as by wavelengths of the visible light. This effect is brought about by fragments of the radiation-induced decomposition of water. The experimental approach can be with the use of external radiation sources or an appropriate beta emitter which would be directly introduced into the solution. It is known that the photosynthetic activity of chloroplast is destroyed only by doses above 10^6 r. Even if the low-energy pho-

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tons from an external source or the bremsstrahlung with about 10 kev, originating from the absorption of beta rays, should disrupt some bonds in the photosynthetic cycle, it can be expected that hydrogen radicals produced by radiolysis of water would result in a net gain in reduction of carbon dioxide. Therefore, if carbon dioxide reduction should occur in good efficiency with lower dose rates, a door is opened to a new and significant approach to these aspects of the synthesis of carbohydrates. Optimistically, that would provide not only for the maintenance of the respiratory cycle in a closed human ecology, but also for food. Hence, it is important to carry through such experiments, especially in view of the possible nuclear propulsion for space vehicles which would easily supply the necessary radiation energy.

Oxygen Measurement

It is proposed that the oxygen analysis be carried out with a polarographic electrode method. This type of oxygen measurement has been under development for many months, and a number of commercial units are under test. The polarographic electrode is a small compact unit that, with minor modification of the existing models, can be made to perform satisfactorily under all required operational and environmental conditions. It will have to be adapted to a special type of sampling system wherein the sample is accurately temperature-controlled. The electrical portion of the polarographic oxygen electrode is very simple, requiring an absolute minimum of space, very light in weight (less than 4 lb), and easily designed to meet acceleration and shock tests. The electrical output of this measurement is minimum 0.1 mv and must be provided with additional amplification since this signal is inadequate for the telemetering transmission system.

Carbon Dioxide Absorption

The absorption of carbon dioxide by chemical means such as lithium hydroxide should be used only as a standby emergency measure, but for continuous operation, the carbon dioxide should

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be eliminated either directly, by a photosynthetic cycle which provides oxygen, or, preferably, by freezing it out from the gas mixture. This is achieved by conveniently utilizing shadow-side temperatures on the moon in a cooling system, through which the gas stream passes with the appropriate volume and velocity. First the moisture will be liquified, eliminating most impurities of the atmosphere. In the second stage, the carbon dioxide will liquify. In this form the carbon dioxide can be stored or used for photo-assimilation.

In the proposed moon environment simulator, the temperatures and pressures are less severe than on the moon, and therefore, for the carbon dioxide freeze-out technique, a special refrigeration system will be used.

Carbon Dioxide Measurements

The measurement and indication of the carbon dioxide content of the capsule atmosphere is fairly complex. Two methods can be recommended for this purpose. The first is to measure the thermoconductivity of an air sample. This is a simple physical property measurement which, under normal environmental and sampling conditions, is ideal for the measurement of carbon dioxide. However, due to unusual conditions — such as a change in pressure, variation in the percentage of oxygen and water vapor, and the presence of relatively large quantities of helium — the measurement is relatively difficult. In order to render this method useful, the following parameters must be incorporated:

1. Utilizing the measurement of the oxygen analyzer to provide a correction factor to the output measurement of the instrument for the variation of the oxygen.
2. Removing the water vapor prior to the sample entry in the thermoconductivity instrument. This assumes that the moisture in the air could never exceed 2% by volume.
3. Maintaining the thermoconductivity cell block at fixed temperature.

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4. Maintaining both the reference and measuring filament at constant temperature.
5. Maintaining constancy of the temperature of the gas sample.
6. Passing a sample gas first into the measuring cell of the thermoconductivity unit, through the carbon dioxide removal unit, which can be ascarite, and finally through the second or reference portion of a thermoconductivity cell.
7. It is assumed that the inert gas component of the atmosphere will be helium and, in this case, the nitrogen content should never exceed 5% by volume.
8. Measuring the power differential between the reference and measuring cell.

Obviously this method is very cumbersome. A relatively unusual feature or requirement of the thermoconductivity measurement is the maintenance of both reference and measuring filaments at constant temperatures. This is necessary because of the unusually large variable of the thermoconductivity for the gas sample as compared to the differential measurement of the thermoconductivity for the span of carbon dioxide to be measured. Theoretically, however, there is no difficulty in designing an electronic control for the precise measurement of these filament temperatures.

The second way of continuously measuring carbon dioxide concentration in the atmosphere is by infrared technique. In contrast to the thermoconductivity instrument, this measurement can be made quite specific to carbon dioxide, and, when measured in millimeters of absolute pressure rather than volume percent, it is independent of the absolute pressure with the exception of the broadening effect due to pressure variables. It seems feasible to use a mono-beam type unit. The analyzer of such an equipment is small — about 3 inches long and 1 inch in diameter — and all improvement according to the state of the art in infrared instrumentation can be incorporated into it. Such an instrument

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should be an electrically modulated beam type, but utilizing dual detectors if feasible. This instrument can be compact and, because mechanical chopping devices are eliminated, all parts and components are rugged and should be well suited for the environmental conditions to which the unit would be subjected. The modulation and amplification circuits will have to be designed to meet the acceleration and shock tests.

Inert Gas

It is not yet decided whether nitrogen or helium should be used as inert respiratory gas. The present state of the art calls for nitrogen. The total gas pressure will be measured with conventional barometric gages.

Humidity

The relative humidity should be maintained at about 40%. It is probable that the total amount of moisture would be removed rapidly from the Moon Base by the freeze-out system and thus must be reintroduced into the life space. This is a straightforward engineering problem with which no difficulties are expected. The humidity in the compartment can be easily monitored with a light-weight hair hygrometer.

Air Purification

The purification of the air of the crew compartment can be achieved by various means. Should power be plentiful and the temperature in the compartment easily controlled, the best method would be to force the air through a tube filled with copper oxide, the temperature of which is kept at 1100°F. On the other hand, if economy in power consumption is called for, and the heat of the purifier (in addition to the 12,000 Btu human output per day) and the heating effect of the electronic equipment could not be tolerated, the organic impurities in the air could be eliminated with chromic acid and charcoal. The shortcoming of this

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system is that the chromic-acid – sulfuric-acid solution will be efficient only at a certain concentration. Therefore, the air must be completely dried before it enters the system, and the necessary humidity must be replaced after it passes through it.

Some of the impurities of the base atmosphere are concentrated in the refrigeration system which eliminates carbon dioxide and condenses water. From the water, impurities can be removed by passing it through an ion-exchange column.

Air Movement

It is quite important that the air movement in the base should be maintained within narrow limits: 1 to 3 ft/sec linear velocity with good average throughout the total cross section of the base.

Section 5

CREW EQUIPMENT FOR LUNAR SURFACE

Great efforts have been made by the Air Force and the Navy to develop space suits and the accessory equipment which will enable the crew to leave the base and operate on the moon surface. There is no space here to describe the details of space suits; a number of unclassified reports can provide the necessary information. Cosmic radiation may reach such levels on the moon that a prolonged stay in and outside of the base can be tolerated only with appropriate protection as mentioned before.

Section 6

EQUIPMENT FOR MAINTENANCE OF CREW'S PHYSICAL AND MENTAL HEALTH

A detailed description of the equipment for the maintenance of the physical health of the crew is beyond the scope of this book. This section briefly mentions the basic principles and will be subdivided into (1) nutrition and (2) medical equipment.

It is quite certain that the energy requirement in sub-gravity conditions will be significantly less than on earth. This depends also on the size of the person, which factor is not in linear function to the metabolism but depends on the Ruebner constant, which is a function of the 0.86 power of the body surface.

In connection with hygiene and sanitary equipment, it should be mentioned that, due to the social atmosphere of western man, no seclusion is required for urination as long as only one sex is present. If both sexes are present, a seclusion, in the English language very properly called a "rest room," is mandatory. Such a seclusion is psychologically most important also in case any of the crew members are overcome by nausea, retching, or vomiting. In public, most people will try to hide their discomfort, and by doing so, they would prolong these unpleasant psychophysiological effects, thus enhancing fatigue, which in turn would result in performance decrement. Provision for bathing facilities or other means for personal cleanliness is an unsolved problem.

METABOLIC REQUIREMENTS

As mentioned before, the total energy requirement on the moon surface will be less than that on the earth due to the dif-

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ference in the gravity. Yet the 1/6-gravity conditions can be simulated in the environmental facility only to a very small degree. Therefore we arbitrarily set the future requirement of one person in the moon base simulator at 3000 calories per day.

OXYGEN REQUIREMENT

For 1 calorie combustional heat, 0.3 gram of oxygen is required. Consequently the daily oxygen consumption is about 2 lb per man. For practical purposes, including safety and various losses, this figure must be doubled.

WATER INTAKE

The total water requirement of man is about 4.8 lb per day. This figure is just an approximation because its value depends upon the amount of water in the urine and feces, which in turn depends on the type of food and mineral intake. Part of the water must be digested together with a food, because absolutely dry food cannot be swallowed. Arbitrarily, we set 2.4 lb of water to be taken in with food and 2.4 lb in the form of beverages.

NUTRIENT FOOD

In the human metabolism, completely digestible fat is utilized at 9 calories per gram. Sugars and proteins will release 4 calories per gram. The diet envisioned for space flight and for pre-flight preparation will contain about 47% carbohydrates, 39% fat, 12% proteins, and 2% minerals and vitamins. The average food will therefore provide 5.1 calories per gram. This food will not be completely digestible but will have about 15% bulk matter. The dry substance of the daily food requirement per man will be therefore 1.5 lb.

One of the most critical items in the maintenance of physical and mental health of the crew members is a question of food. This problem is far from being solved. The difficulty lies in the high complexity of the psychophysiological factor called appetite.

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If the nutrient material and water is not taken in voluntarily and with pleasure, the calculated nutritional values will become erratic. Furthermore, if the food is forced down by the crew, it is expected that disturbances will occur in the gastro-intestinal tract which, through the sympathetic nervous system, will have a feedback and could cause severe performance decrement. It seems that our astronauts will have to have the best food of their choice, regardless of the costs involved. Perhaps, after long and gradual indoctrination, this effort can be relaxed until eventually the significance of "eating" will be psychologically degraded to "nutrient intake," and thus concentrated artificial food will be accepted by the crew without performance decrement.

CARBON DIOXIDE RELEASE

The respiratory quotient of the normal metabolism is 0.85. This amounts to approximately 2.2 lb of carbon dioxide per day. If chemical absorption of this carbon dioxide is required and lithium hydroxide is used, the requirement per day will be about 3 lb. Due to the fact that the absorption capability of lithium hydroxide pellets is nonlinear, the practical amount should be set at 6 lb per day per man, which rate would not include the aspirator and the container. This would be an intolerable weight for long lunar missions unless the regeneration of the exhausted absorbant is provided.

WATER OUTPUT

Part of the digested food is metabolized in the human body to form water. This water, which is about 0.7 lb per day per man, will show up in the total water output of the human. Under the environmental conditions which are expected in the crew compartment, the water output of a crew member will be:

Perspiration	1.1 lb
Exhalation	0.8 lb
Fecal water	0.4 lb
Urine	2.2 lb
TOTAL	5.5 lb

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It is important for design purposes to distinguish between the eliminated liquid water to be found in the urine and that of the feces which, together with the 0.2-lb fecal solids, will amount to 3.8 lb. This should be stored in polyethelene bags for less than 6-day missions, or should be buried on the moon after chemical sterilization to avoid contamination of the moon surface with terrestrial bacteria, which would interfere with the research of space microbiology.

Section 7

COMMUNICATION

In the field of lunar communication and telemetered data processing, large sums have been spent for research.

Experimentation and contractual experiences have helped to develop a large number of different basic approaches to lunar communication. Many of these aspects have passed the feasibility study, and in a number of cases, even the hardware is available from the shelf. The only task which is left for the completion of the development of lunar communications is an intensive study of the available and applicable systems for the determination of the optimum configuration as far as weight, space, reliability, and economy is concerned.

The field of lunar communication can be broken down into:

1. Lunar surface communication
2. Transceiving of messages with earth

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3. Transmitting of data obtained directly from individual transducers
4. Data processing.

Each of these four sections has a number of important features, but only a few should be mentioned here.

The main problem area seems to be the basic decision for the required information flux and its temporal distribution. The first task should be the determination of the equipment weight in the function of information flux. In the basic design, there will be, no doubt, a minimum amount of information which is required for the maintenance of operational efficiency of the Moon Base. The next pertinent question is that of the price one is willing to pay for more information capacity.

Since various agencies have already used the moon as a passive reflector for point-to-point communications, the actual path attenuation between moon and earth will be readily determined from existing information. Preliminary investigators have indicated that absorption, reflection, etc., would be excessive in the present 220-mc telemetry band. In addition to this, there is a problem of galactic noise, or the so-called radio stars, which causes interference in the r-f link. Furthermore, it can be expected that some heretofore unknown problems, which could arise due to cosmic and solar radiation, will have to be overcome by lunar transmission.

At the first approximation, the use of the 2200–2250 mc wavelength band seems to have the greatest advantage because it will lessen the noise and absorption problems considerably. One of the shortcomings of this wavelength band, however, is the difficulty of pointing the large antennas.

It is expected that, for a lower average power requirement, pulse transmission such as the PCM system will be used. A number of advanced techniques for pulse detection, correlation, maser amplifiers, etc., may be taken into consideration. The next important step would be the determination of required signal-to-noise ratios as a function of information capacity. Extensive research and development work has provided excellent insight into

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this problem. Further study will include such items as the establishment of the number of channels, sampling rates, and bit rates with their attendant wavelength band requirements.

Special attention will be given the application of time multiplexed pulse position telemeter and pulse code telemetered systems, because they are the optimum methods for a radio link.

Hereby we encounter certain limitations due to quantum-mechanical considerations with respect to the uncertainty of the momentum of propagated energy. This brings about a spread of the signal wavelength band, which in turn reduces the number of possible channels. The shorter the pulse, the more pronounced is this effect, which is, however, insignificant for microsecond pulses of 2200-mc signals — namely about 10^5 Å wavelength.

Another loss occurs through size limitation of the transmitting antenna. This brings about a diffraction which is due to the uncertainty of transverse momentum and results in the spread of the wave package. This factor is a function of the distance and will reduce the transmitted energy between moon and earth by a factor of 10^{20} , assuming a 2200-mc signal, a 6-ft transmitter, and a 60-ft receiving antenna.

The next logical step would be the determination of the power source. A few companies are doing quite extensive work on some unconventional power-source systems suitable for use in satellites and space stations. These include such items as solar cells, small nuclear reactors, radioactive primary cells, isotope batteries such as SNAP-III, and so-called chemical cells. In some of these, the lack of atmosphere on the moon presents some intriguing possibilities. By closer analysis, it turns out, however, that the problem of power source is of secondary importance due to the fact that most of the amplifying equipment will use primarily solid-state systems. Furthermore, the Moon Base itself will have a primary power source for its many other functions, and the communication system will make use of this.

It seems quite feasible to consider very large antennas for the moon surface with diameters of 250 feet, such as the Cambridge telescope, or even surpassing this. Such an antenna could be constructed from a large balloon inflated with carbon dioxide.

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The lower surface could be metallized and the maintenance of the parabolic contour could be achieved by re-enforcing ribs which are molded into the skin. Such an antenna would be very lightweight, and the pointing problem could be handled by rolling the ball on the surface of the moon. The lack of air and wind and the low gravity would facilitate this. The development of such an antenna system is now in progress.

LUNAR SURFACE COMMUNICATION

The lunar surface communication does not set any problems. A simple low-powered transistorized transceiver which could be built into the space suit would probably be quite satisfactory. Due to the probable lack of ferrous metals in the lunar surface, such a device would be operational even through large obstructions such as rock formation. To determine the action radius of such a transceiver, it is necessary to obtain information concerning the chemical constituents of the lunar surface and about lunar magnetism. I am already working on the design of the equipment for accumulation of such information during the next lunar probes.

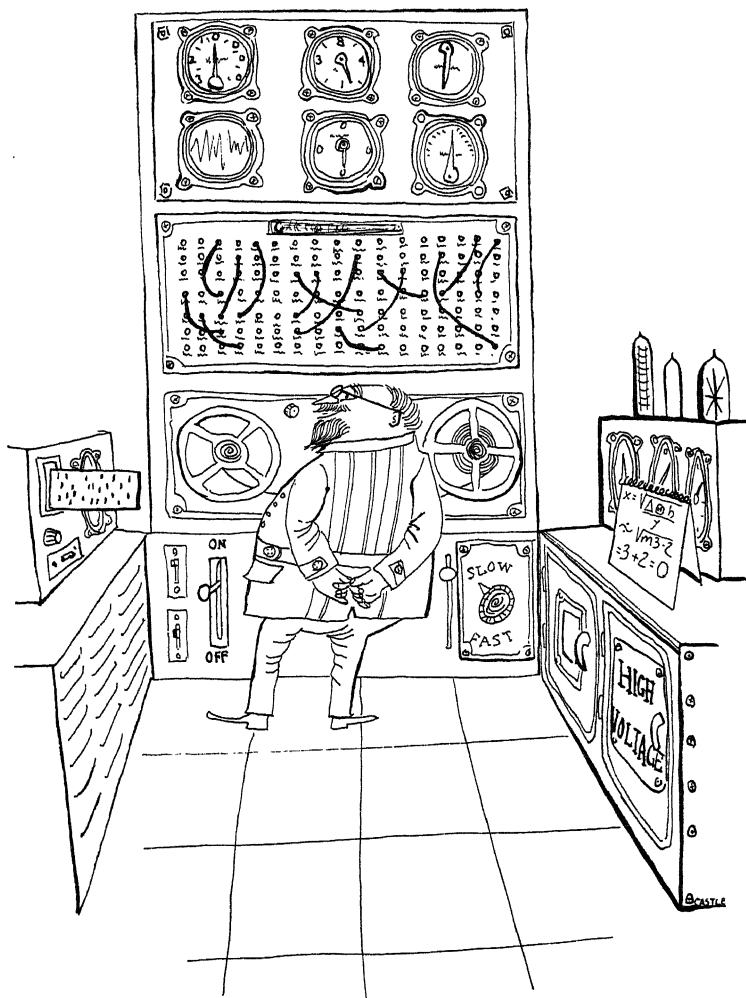
EARTH-MOON COMMUNICATION

For various technical reasons it is quite unlikely that, at first, for the transmitting of messages between moon and earth, a telephonic transmission of live voice would be used. It is more likely that the messages would be coded and transmitted by means of pulse radar. Attention should be given to the selection of the coding and decoding device, because it would bear great psychological importance if the decoded message had a high tonal fidelity. This point, however, would require a major breakthrough in this field, and for the establishment of a communication link, it is not essential. Theoretically there is, of course, no serious difficulty in the construction of a telephone or video link.

It would be quite important to establish a video circuit over the earth-moon r-f link. For years after the Moon Base is estab-

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lished and operational, the monitoring of the activities on the moon will be vitally important. Transmission of pictures will provide much greater information content than written or spoken



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messages. Also hallucinations in the crew members may occur due to environmental stresses, and the best psychological counter-measure would be the demonstration of the factual environment and the lack of verification of the hallucinate content by the video. Furthermore, certain pathological symptoms of the crew could be much better diagnosed from earth if a video picture were available than if the symptoms were only described. Thus better medical assistance could be provided from the earth.

AUTOMATIC DATA TRANSMISSION

A large volume of the communication will be occupied by automatic data transmission. Certain vital factors — oxygen partial pressure, radiation flux, etc. — may reach critical levels without being observed by the crew. Such data are transmitted directly from individual transducers. This transmission will occur automatically at predetermined time intervals and the system will be inaccessible to the crew members. Again, other data representing research information and messages of lesser urgency will be fed into magnetic memory drums and transmitted whenever the communication system is unoccupied, or when telemetering channels are available.

DATA PROCESSING

Concerning the processing of data transmitted from the moon: it should be emphasized that we have several programs, involving digital data processing, underway. These include the Vanguard Digital Data Processing system, the Thor Guidance Data Processor, and several others of classified nature. All of these systems are concerned with the transmission, collection, processing, and reduction of just such data as would be expected from the moon.

Part II HUMAN FACTORS

Section 1

ESTABLISHMENT OF THE OPTIMAL SMALLEST NUMBER IN CREW

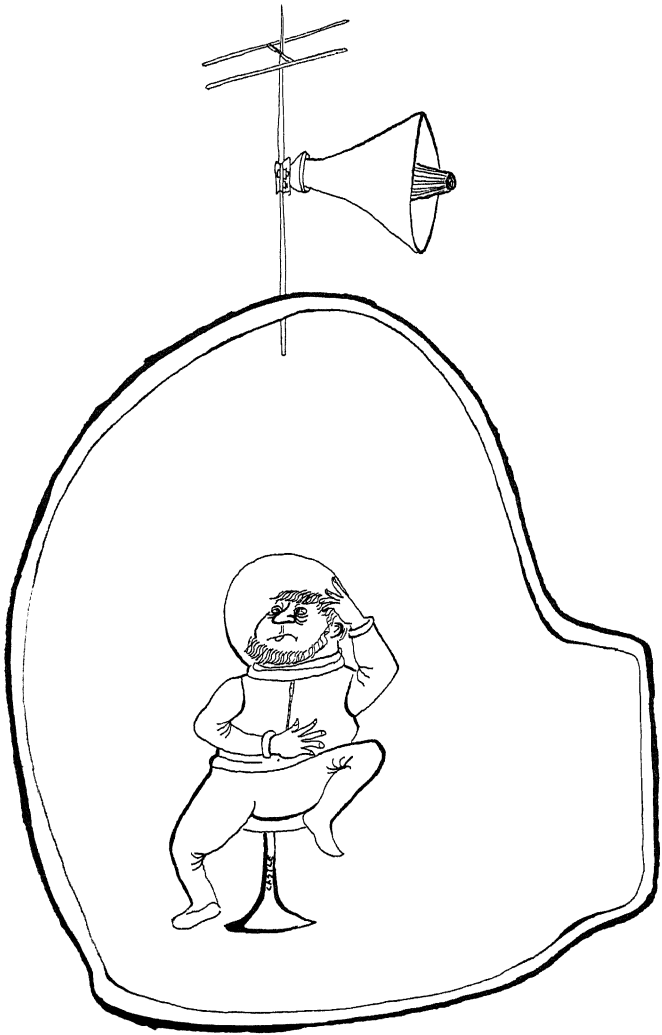
SINGLE-OPERATOR PARAMETERS

The most desirable weight-saving method of staffing a Moon Base would be to occupy it with one man. The expected demands of the mission, however, far exceed the capabilities of single operator.

The most obvious factor in the task, as it is envisioned for a lunar research operation, is the high degree of attention which the mechanical system of the base will demand without letup. The many unknown factors and possibilities, as well as communication with earth, will require continuous monitoring which would not allow time for rest. Another argument which would exclude the one-man system is evident from the necessity of permanent vigilance for emergency situations, such as a meteorite strike. Furthermore, the mission profile of a lunar research

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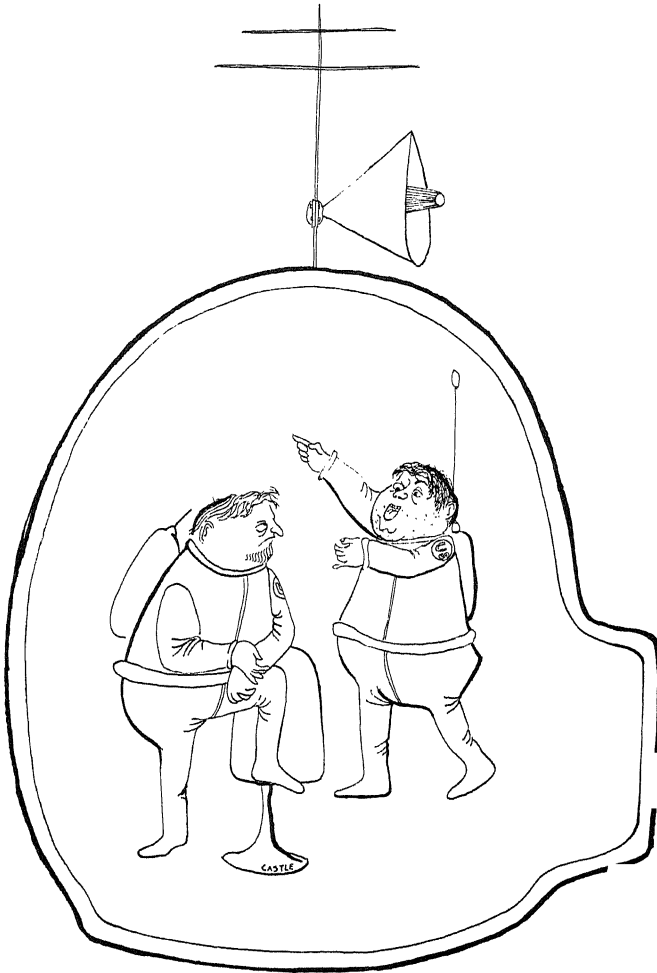
base is mainly concerned with the collection of scientific data and the gathering of such information will involve expeditions on the lunar surface. The elements of safety will therefore re-



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quire that at least one person be stationary in the base to supervise the equipment and to monitor the activities of the person outside the base.

It is not inconceivable, however, that, after the reliability barrier of the equipment has been broken through at some later



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period, some low-stress, short-sleeve mission profile can be designed which could fall within the capabilities of one operator.

DUAL-OPERATOR PARAMETERS

Two Males

The next progressive step in the choice of the minimum optimal crew number would be the selection of two male personnel. Again, the length of the mission and the requirements of equipment and research duty are overwhelming.

Even if the work cycle were arranged in a manner such that one operator would always rest while the other works, the situation would not be improved over the one-man system operation. Forwarding information to earth, maintaining the base equipment, and functioning on the outside of the base could not be carried out by the one working individual while the other is resting.

The social interaction between two men living together for a prolonged period in the cramped environment must also be taken into consideration. If hostility is to be avoided, interaction must be achieved and should occur in a satisfying manner. The necessity of duty in a two-man system would leave each operator so exhausted that sleep would be a treasured reward and could eliminate therapeutic and relaxing idle association.

Much research is expected in the Moon Base prototype for the investigation of the possibilities of two-man operations of a less taxing nature. Cis-lunar and orbital flights or lunar missions lasting under two weeks could perhaps be more economically accomplished using such a crew number. Some of the interesting problem areas there would involve personality frictions, work and rest cycles, diversion, duration of duties, etc.

One Male and One Female

Another combination also should be mentioned: a team composed of a man and a woman. However, certain missions may require a taxing physical burden with which the female physique

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could not cope without severe performance decrement. In addition, the compensatory behavior of the male in such a situation would perhaps be detrimental to the total team output due to fatigue and emotional stress.

THE THREE-OPERATOR SYSTEM

The selection of three individuals for the optimal minimum Moon Base crew complement seems to provide the most efficient means by which to complete the mission. Although more than three personnel might be desirable for the over-all success of the mission, weight and space parameters will set severe limitations to any greater number at least in the near future.

With the use of three humans, it is far simpler to design a work-rest cycle by which one person is at rest at any given time, with the two remaining to carry out experimentation and system maintenance.

Under such a schedule, recreation and other boredom-relieving factors could be utilized with greater frequency and for more sustained time periods than could be realized with crews of a lesser number.

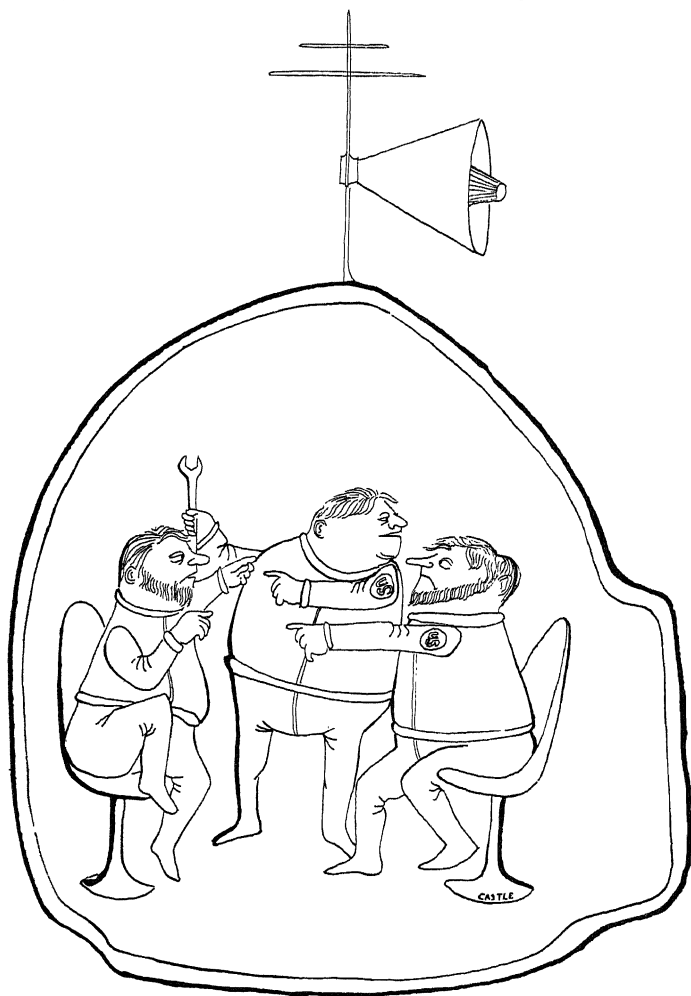
Work involving the operation of a human outside the ecosystem requires close visual or radio contact with another operator who is safely within the base. In case of emergency, imminent and direct aid requirements can be met and the base would still contain a human who could serve until the emergency situation is dissipated. With a number smaller than three, such a basic pattern could not be realized.

In considering a three-operator system for the proposed Moon Base prototype, we are aware that power coalitions may tend to form, thus disturbing any preselected command chain. A Moon Base prototype can be used to validate various theories of coalition formation within triadic systems.

For a mission of the length envisioned for the Moon Base, it is most important that efficient and compatible personnel be grouped as a crew. Less obvious is the pertinence of the ratio of sexes in such a unit.

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The experience of the Navy for situations of close confinement for lengthy, womanless periods has shown that such groups can stay operational for as long as many months. These experiments, however, cannot be extrapolated for the conditions as they will prevail at the Moon Base. Because weight considera-



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tions set extreme limitations on the crew number, the individual task burden can be satisfactorily carried only if the crew is operating with maximum efficiency. Therefore, contrary to the Navy experiment for ships or submarines, even minor irritations and interferences which could be psychologically or physiologically detrimental to the performance must be avoided.

Optimum: Two Men and One Woman

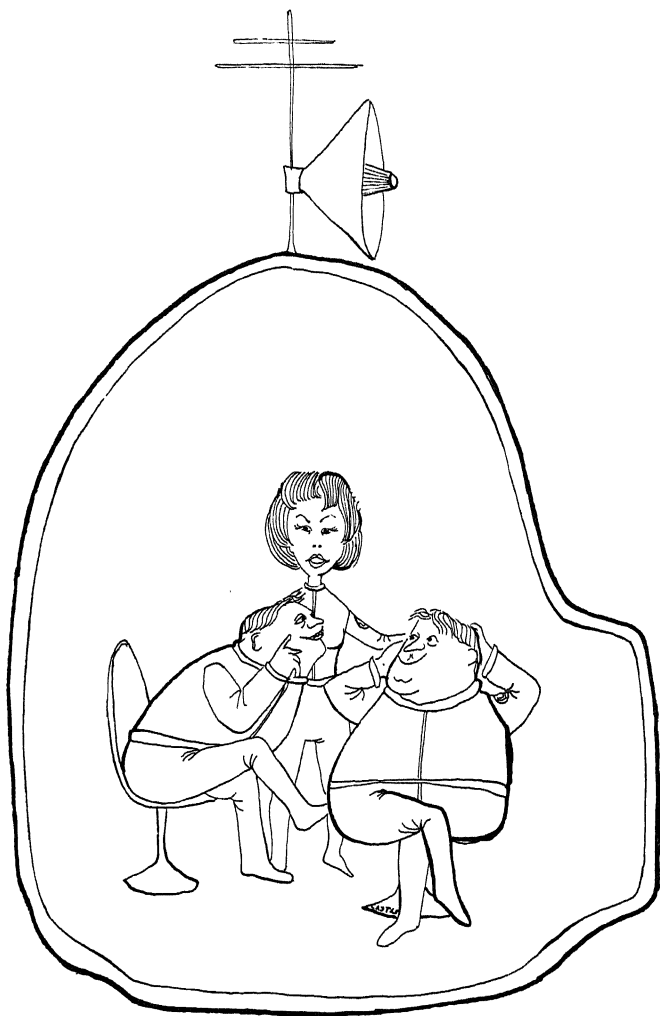
These considerations have led to extrapolations from fundamental western social traits and limited influences to the hypothesis that a ratio of two males and one female might provide a more proficient crew combination. There are a number of arguments which indicate that such a ratio would have definite advantages over a system utilizing three males. The cultural suppression of hostility and, to a lesser extent, inhibition of sexual tendencies would perhaps operate more efficiently than in a system where only same-sex peers are involved. Agression, whether overt or internalized, seems to be a function of growing or dis-inhibited hostility. This could be detrimental to a Moon Base mission, and it could greatly alter its functional profile. Thus it must be eliminated.

In addition, the woman in the system could have the effect of providing an inhibitory catalyst on agression through the action of the cultural feature, and her presence would elicit the tendency of the male to display himself positively before the female. These factors could have the property of prolonging the essentially healthy emotional atmosphere within the Moon Base and could also minimize the influence of hostility where it did appear. Such inhibition would imply no more stress than any similar earth-bound situation, at least for a considerable length of time.

As the mission lengthens into months, however, the curbs, more or less unconsciously imposed by cultural influences, may have to be partly supplanted by verbal inter-diagnosis among the crew. This constitutes an intellectual airing of problems that could greatly add to the emotional adjustment. It is expected

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that there may appear some cases where some individual may prefer self-analysis and control over the aforementioned therapeutic methods. The type of persons selected for the Moon Base operation will have to have the fundamental ability to analyze



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group feelings, verbalize or compensate inwardly, and adjust their behavior to maximize the possibilities of optimum crew member interaction.

Channeling of unavoidable sexual and hostile energies into areas of usefulness to the mission is a basic requirement. Libidinal energy may even have the function of incrementing the performance of certain individuals. Hostility, although recognized as irrationally derived, could be nurtured by such an individual as a promoter of his over-all drive level. In any case, the alleviation of detrimental effects resulting from sex tensions and hostile tendencies should not preclude examination of their basic origin as a continuous function of insight.

It can be considered as a great advantage of the proposed Moon Base prototype that psychological testing and performance observation of the personnel and its specific training can be carried out under high-fidelity simulated conditions which would give an opportunity to experiment and observe the degree of integrative or non-integrative coping with problems displayed by the individual crew members.

Should fatigue or emotional stress reach a point where the performance output begins to drop off severely, it may be necessary to utilize drugs or certain relief methods to assure a return to the expected level of operation. Part of the study of the Moon Base prototype would extend to determine the long-term effects of such depressants, stimulants, and other psychomimetic drugs on the over-all performance. The possible decrement arising from the use of such drugs could be evaluated and compared with the adjustment which they would provide.

In arriving at the basic optimal crew complement of two males and one female, the question of possible malfunction in the system as a result of human factors was not overlooked. Some of the suggestions as to what particular aberrance in the social field might result in lowered proficiency are the following:

1. The inhibiting effect on undesirable male tendencies, based on the presence of a female, may tend to diminish as a function of time and increased familiarity.

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2. There is a possibility that a real rivalry will begin to take place for the favors of the female, with dissention and combat arising.
3. The possibility has been advanced that the female of the system might choose to her liking one individual, with relative exclusion of the other. This could be represented as social or physical preference, or both.
4. The female could tend to experience a degree of loneliness for a companion of her own sex.

Although these and other factors exist as possibilities in the operation of the Moon Base, they can only be established as present and detrimental through testing. In selecting three as a basic number, consideration was given to the probability that four crew members, with a ratio of 2:2, would perhaps be more optimal. However, weight restrictions do not permit such extravagance at the present state of the art. The addition of one more crew member, for example, to form a team of two husbands and their wives, would result in a 30% increase in crew space, and a total ship-weight increment of about 100,000 lb. This is not justifiable until the merits of small crews have been carefully investigated.

Section 2

EFFECTS OF INTEGRATED ENVIRONMENTAL STRESS ON INDIVIDUAL PERFORMANCE

The evaluation of stress tolerance and motivation for Moon Base operations is made easier, but not eliminated, through test-

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based pre-selection of the crew. There must be a manner in which marginal and questionable volunteer candidates can be rejected with a high degree of efficiency and accuracy.

Individual criteria for lunar missions are, in general, as follows: great ability to master the machine complex and to exist optimally within the artificial environment; psychological stability; proficient judgment under pressure and ability to deal maximally with emergency situations. Furthermore, a broad technical background and high professional skill, as well as a strong physique, are requirements which are self-evident.

The selection criteria as they are applied to high-performance flight personnel, as for the Mercury capsule, can be only partially applied for the evaluation of crew members of the Moon Base. The reason for this is that the Moon Base personnel will be operating in a social field for much longer periods of time. Furthermore, the human link in this man-machine system of the Moon Base is closely integrated with the continuous operation of the system. This is in contrast with the task of the human element in the Mercury project, which is restricted to the monitoring of the fully automatic devices and will perform any psychomotor function only in case of malfunctioning or other emergencies.

For the volunteers who meet experience requirements, screening procedures prior to advanced training and further selection are basically now conceived. These include size and weight parameters; physical, psychiatric, psychologic, and psychophysiological examinations; and general review of history, including past evaluations.

However, these preliminary standards for screening candidates will, by nature, be partly based on subjective judgment unless they are backed by pertinent and adequate scientific data. General areas of stress-producing factors on individual performance, with the exception of low gravity, could be more realistically and penetratingly investigated within a moon environment simulator. Such factors are:

1. Ecosystem environmental aspects peculiar to space and lunar-equivalent conditions (pressure, temperature, gas constitu-

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ents, meteor impact, illumination, food and elimination, ionized air, magnetic fields, available light, etc.)

2. Reliability of equipment
3. Low gravity
4. Sleep deprivation
5. Isolation
6. Boredom, fatigue, and aggravation
7. Efficient work and rest periods
8. Psychophysiologic and psychophysical aspects
9. Cumulative effects
10. Leadership
11. Individual and group emotional problems (compatibility)
12. Design of optimal crew environment (anthropologic and comfort features)
13. Compensation for reduced number and frequency of perceptual feedback variables, as within a space suit or under low-gravity conditions
14. Control panel and display design, including communications and information handling
15. Establishment of minimal human privacy devices
16. Effectiveness of ground control on remote man-machine systems, including interaction of ground and space vehicle control teams
17. Observation of emergent social sub-systems

It is felt that rigorous testing and examination of every related potential problem area should precede selection of tentatively qualified personnel. Furthermore, separate consideration of the seventeen problem areas mentioned here is paramount to

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designing space-craft living and work environs, and for diagnosing, predicting, and reducing individual susceptibilities. Yet final testing of the man-machine complex for so-called "space-worthiness" can come only through the employment of suitability tests in a highly adequate, ground-based, space-equivalent simulator.

Section 3

GROUP INTERACTION UNDER SPECIFIC ENVIRONMENTAL STRESS CONDITIONS

Once the individual performance parameters have been established using the methods already outlined, compatible individuals may be tentatively grouped for purposes of crewing.

Although the optimum manner for assembling such a crew seems to be assignment according to over-all performance record, personal preference, and trait similarity, studies have indicated that individuals tend to contribute differently to the group product according to the individuals with whom they are placed. This factor, called the "assembly effect," renders less credence to performance predictions of a given crew according to level of individual proficiency.

In addition, some deprivations not associated with short-term flights become influential when two or more humans are involved in a mission lasting more than two days. These include sex, group coordination, recreation, alcohol, etc.

Furthermore, problems associated with man-machine coordination for optimal stress-free output may not become apparent until the actual mission has begun. In this area, much practical research needs to be done, including work loads, psychological

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effects of performance displays, privacy within the life space, depletion of crew number, etc.

The need for a simulated space environment, duplicating as closely as possible the actual mission requirements and beyond, becomes apparent. The so-called "assembly effect" mentioned here can be validly quantified only as it occurs with all relevant factors in operation. A realistic simulator surpasses, in scope, reliability, and training, tests designed to reveal only individual tasks, group coordination, and performance parameters.

Section 4

DESIGN OF ROUTINE TASK PROGRAM

If the great expense of the Moon Base venture is to be justified, it must be in terms of what the human operators and their equipment can contribute while engaged in scientific activities there.

For purposes of exhibiting the various portions of what is now envisioned as a tentative lunar outpost daily schedule, tasks will be divided into those of a routine nature and those more specific.

A. Routine

1. Normal duty-rest time cycle
2. Programed maintenance — periodic equipment checks and recording
3. Allotted recreation periods
4. Console monitoring periods
5. Eating periods and, if needed, preparation of food
6. Elimination breaks, if movement from duty station required
7. Crew "policy" and decision meetings

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8. Exercise periods
9. Training periods
10. Medical examinations and telemetry of data
11. Scheduled base and earth communications

B. Specific tasks

1. Outdoor work
 - a. Astronomical, biological, etc.
 - b. Mining
 - c. Communications, shell-to-outside
 - d. Shell-to-outside visual monitoring
 - e. Exploratory
 - f. Emergency measures
 - g. Space-suit assistance (application and removal)
 - h. Space-suited indoor activity.
2. Emergency duties and schedule changes
 - a. Loss or impairment of crew member
 - b. Meteor impact on shelter
 - c. Earth-base communication failure
 - d. Ecosystem environment equipment breakdown
 - e. Relief ship arrival failure
 - f. Attack by hostile factors
 - (1) Covert (radio jamming, etc.)
 - (2) Overt (weapon penetrations, etc.)
 - g. General deterioration of crew performance parameters due to cumulative stress effects.
3. General equipment repair

Until the actual Moon Base prototype internal equipment has been made known, with its accompanying performance parameters and "idiosyncracies," establishment of a temporal schedule is not possible. This is especially true in the areas of maintenance, monitoring, and emergency task development.

Work especially needs to be done in the field of increased stress resulting from the loss of a crew member (or his impair-

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ment), with the inevitable increase in work load on survivors. Equipment should be designed with such a possibility in mind so that resultant hardship is minimized.

Finally, it is necessary to consider the possible effects of human operation under sustained subgravital conditions. Since there is no way to provide satisfactory training for this phenomenon on earth, we shall have to wait until planetary landings determine possible degradive effects.

RECREATION IN THE CLOSED ECOSYSTEM

The study of this question as it is described in the following deserves very high priority. The mentioned procedure is tentative and can be altered if the preliminary studies so require.

The alleviation of fatigue and the mitigation of stress effect through recreation is a problem area that should receive extensive study as a preparation for the optimum functioning of man under space-equivalent conditions.

There has been very little research, if any, done so far in this area that could apply directly for Moon Base conditions.

Parameters that will effect the mode of recreation are basically the following:

1. Time and effort factors of duty cycles
2. Length of mission
3. Space available for recreative activities
4. Group interests
5. Individual interests or hobbies
6. Low gravity and other limiting conditions

The space crew area has to be designed according to the feasibility governed by the uniqueness of its environment, and recreation should conform to these resulting configurations, such as payload limits.

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It should be mentioned here that only very few of the results or observations gathered from long-lasting submarine missions can be utilized for Moon Base recreation, but nevertheless they should be taken into consideration. So little reliable knowledge can be obtained from speculation in a field where pertinent factors are largely unknown that satisfactory results can only be expected from practical experiments in the Moon Base prototype.

To test their recreational effectiveness, a few randomly chosen items should be mentioned here. These are: taped music, art work, such as painting or drawing, but excluding sculpturing which requires too much space and weight; filmed reading material; plant cultivation and animal mascots, provided their drain on the resources of the ecosystem is not objectionable; radio and television if channels are available, etc.

Section 5

MEDICAL PARAMETERS

Although it is mandatory that one of the crew members be thoroughly trained in medicine, it is possible that a crew member will show symptoms of illness which is psychosomatic in nature and is caused by environmental stress. These symptoms may not be diagnosed properly by the crew, and therefore the transmission to earth of certain biological factors becomes necessary. Reliable information can be obtained from telemetered data where the only task of the crew would be the proper placement of transducers.

The simultaneously transmitted information on the following factors are recommended for various combination:

1. Cardiogram

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2. Respiratory rate and volume
3. Blood pressure
4. Electroencephalogram
5. Muscle activity
6. Reflex activity
7. Galvanic skin response
8. Body temperature
9. Activity of the gastrointestinal tract
10. Food and water intake
11. Urine and feces excretion
12. Blood cell count

CARDIOGRAM

The action potential of the cardiac muscle is registered easily and the signals are well understood. This factor is presently the best known for telemetering and is one for which a satisfactory technique has been worked out. The signal from the heart muscle is strong enough to remain legible even during the noise created by muscle potentials if the body is not at rest. There is need for improvement in the electrode application and in the reduction of the number of electrodes. There are, at present, four stationary electrodes required, with one additional probe to obtain signals from different points of the chest. Since the five check points on the chest are taken in a sequence, it is probable that the five records can be telemetered through the same channel by time sharing.

RESPIRATORY RATE AND VOLUME

It is conventional to use strain gages for these measurements and the results obtained are satisfactory. The response of the

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strain gages is good, and the signals can be transformed easily into the appropriate frequency or wavelength band.

BLOOD PRESSURE

The only accurate technique for obtaining precise blood pressure values is by vein puncture, which cannot be applied for obvious reasons. There are, however, a few other methods rendering fair approximations with the use of sphygmoscopes. This factor requires further improvements, but a channel in the r-link must be reserved for it.

ELECTROENCEPHALOGRAPH

Great efforts have been made to perfect this technique, yet there are still many difficulties which have not been overcome. Under very carefully controlled laboratory conditions, the EEG will render important information, but under field conditions, the present state of the art will permit only the indication of sleep or wakefulness. One important problem in the development of EEG is the interference of the noise caused by muscle potentials which can be stronger than the brain signals. The electrodes are also a problem because intracutaneous needles cause discomfort, and surface electrodes will show artifacts unless the subject is completely immobilized, which, in this case, would strongly influence the normal bodily functions. A good possibility is the application of chronic electrodes embedded in the brain. In animals this has been a successful technique with no side effects, and it is thinkable (although an unpleasant thought) that the same method should be used for man.

MUSCLE ACTIVITY

It is important to grant as much freedom of motion to the persons as feasible in the capsule, and it is necessary to transmit the extent and rate of motion. Muscle activity can be recorded by the electromyograph which picks up action potentials through

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a set of properly placed electrodes. The number of sensors has to be determined, but it is probable that a scanner will make sequential probes over all electrodes and thus will use only one channel for this parameter.

At this point, it seems to be opportune to draw attention to the complexity of the lead harness from the sensors and transducers. It seems to be out of the question that all those wires should be connected to a stationary unit. The only solution is to design a transistorized relay unit which is carried on the body and which transmits the not-coded or partially coded signals to the main transmitter in the compartment. This seems to be a challenging task for an ambitious electronic engineer or communication specialist.

REFLEX ACTIVITY

It would be detrimental to the normal function of man if there were complete silence and darkness in the base. Therefore, it is planned to have a random noise of about 15–20 db and an ambient illumination of about 5 millilamberts present. At random time intervals, visual and audio stimuli of higher intensity should be applied and the reaction time measured. The instrumentation is simple and presents no problem for telemetering.

GALVANIC SKIN RESPONSE

The electrical conductivity of the skin is widely used in experimental psychology and for lie-detector tests. The value of this parameter is still under discussion, and the information is incomplete as far as primates are concerned, but it is more reliable for humans.

BODY TEMPERATURE

The measurement of the body temperature can be accomplished readily by the use of thermocouples and their signal transmitted through a transistorized oscillator circuit. This informa-

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tion is meaningful only if it is available simultaneously with the ambient temperature of the crew compartment.

ACTIVITY OF THE GASTROINTESTINAL TRACT

Space medicine is strongly interested in this factor because there are a number of problems in connection with the type and quantity of food and the time intervals of feeding of the space crew where this information is invaluable. The same data correlated with others would be greatly enlightening in the interpretation of behavioral patterns and emotional reactions. The measurement from the lower colon can be obtained by inserting an open tip catheter which is connected to a pressure transducer. The signal can be fed into a bridge circuit and the output telemetered. The mobility of the stomach can be monitored by implanting a small magnet in the stomach wall and registering its motion with a sensing element from outside the body. At first, this seems to be somewhat far-fetched and inapplicable to humans, but for space flight, we will have to become accustomed to unusual procedures in our attempt to make the human organism fit for space environment.

FOOD AND WATER INTAKE

It is probable that an attempt will be made to develop a single uniform liquid food. During ballistic flight and due to the weightless condition, the food has to be sucked from a container. If the bottom of the container is free to move, its motion will indicate the quantity of the food intake and can, if required, also govern a sensor for telemetry. It must be borne in mind, however, that a prolonged use of uniform food, even with different flavors, may cause aversion in the crew.

URINE AND FECES EXCRETION

It is quite important to measure elimination under space-equivalent conditions. This requirement is very difficult to ful-

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fill, which seems amazing at first, but there are biophysical design problems which have not yet been overcome. As long as the complete utilization and cycling of food and waste matter is not solved, the difficulties of their control are severe. The utilization of plastic containers is satisfactory only for short missions. If the odor of the excretions and bowel gases can enter the Moon Base, they must be eliminated completely to avoid serious reactions. The excretions could theoretically be filled in a cylinder and the quantity measured with the use of a radio-isotope gage. However, a useful signal for telemetering purposes is not yet available and verbal information seems the best for the time being.

VOICE TRANSCIVER

Significant information can be obtained from telemetered noises — conversation, snoring, etc. — of the crew. It would also be valuable to know in what manner the voices of the ground crew and loved ones could reduce excitement and anxiety. Thus, transmission of audio frequencies in both directions is a definite requirement.

In addition to these biological factors, some environmental parameters, such as carbon dioxide and oxygen partial pressure, are required.

Section 6

DENTAL PROBLEMS

It is self-evident that an infected and aching molar will not only reduce the performance of a crew member, but if the situation is aggravated, without proper care under the prevailing

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severe environmental conditions, it might cause rage or even insanity, and thus endanger the whole mission.

It can be shown that even a thorough preflight dental examination may not reveal small infections or small lesions in the oral cavity. On the other hand, it is unthinkable that a 6-month or longer stay in the lunar base have the prerequisite that all 32 teeth of the crew member be pulled. It is, therefore, imperative that the proper dental care of the crew on a long-lasting moon mission be carefully analyzed.

This problem syndrome can be subdivided into three parts: (1) preflight examination and acclimatization, (2) preventive hygiene, and (3) therapeutical measures.

PREFLIGHT EXAMINATION AND ACCLIMATIZATION

The expected preflight liability of caries in the Western man is approximately 98%. It is therefore unlikely that a candidate will be found without tooth decay or, to some degree, reconstructed tooth surfaces. These restored surfaces of teeth can be considered as potential spots for trouble in flight or during the stay on the moon's surface.

The predisposing factors to dental caries are manifold. Some of these factors are the prevailing bacterial flora in the oral cavity, microscopic defects in structure-enamel lamella formation, and inherent organismal characteristics. These organismal and inherent characteristics can be: tooth form, biochemical constitution of the tooth substance, the enzymatic action and alkalinity of the saliva, etc. Primitive societies do not appear to have this problem of caries and oral flora concentration because dietary considerations are the reverse of the civilized diet. For the primitive diet, high roughage content is present, and there is almost a total lack of refined carbohydrates. Due to the high roughage content in these diets, which requires prolonged mastication, a self-cleansing of the teeth is achieved.

Some of the preflight examination items are:

(a) All improper fillings must be replaced and the thoroughness of procedure must be followed up by x-ray control.

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(b) All impacted wisdom teeth must be removed.

(c) To detect marginal conditions which cannot be diagnosed in the clinical dental examination, crew members should be exposed to positive, negative, and transverse acceleration in a centrifuge. It can be expected that, by this treatment, small lesions of the terminal fibers of the superior and inferior dental nerve would flare up due to the alteration of the normal capillary blood flow. This treatment, of course, will not reveal latent lesions in every case, but it will increase to some degree the reliability of the preflight examination. A second such treatment would be to place the crew members in an altitude chamber under a simulated altitude of 12,000 ft for prolonged time. It is expected that, because of the mild hypoxia and the low external air pressure, any small vacuole or gas pocket in the nerve canal of the tooth would expand and cause pain by pressing on the nerve. This, then, would indicate to the dentist that treatment of that particular tooth is necessary.

HYGIENE AND CARIES PREVENTION

When a candidate presents himself for space flight and for long-lasting isolation from earth environment, he is physically and mentally the sum total of his individual life forces with the result of and compensation for the multitude of physical and psychic insults and experiences he has received to the point of his mission commencement. This organismal response is reflected in the whole body and is seldom more overlooked than in the case of oral conditions. Besides the examination of the preflight status of the crew members' oral conditions, it is most important to find modes of prevention of mouth disease and its treatment in space flight. It is quite unlikely that, in a three- or four-man crew for a long-term space flight or for a lunar space laboratory, a dentist could be included. Therefore, the need of simple and direct methods of coping with the problem is vitally necessary, since painful situations or gross malfunction of the masticatory mechanism can completely incapacitate the individual for mission accomplishment.

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According to dental authorities, oral hygiene is of little importance in caries prevention, provided that the diet is properly controlled to prevent hydrolyzable carbohydrate from contact with oral bacterial flora, thus preventing acid plaque formation and thereby stopping enamel etching which can initiate the carious process. Civilized man's soft-diet of highly refined food contains insufficient roughage for providing natural cleansing during mastication. It is, therefore, apparent that bacterial colony growth, in the absence of good hygiene, would soon reach an intolerable level. The diet, as we envision it for a prolonged lunar mission, will have a high carbohydrate content and will be almost completely void of indigestible rough fibers which could exert any cleansing action during mastication. Therefore, a mechanical cleansing, with the addition of some chemical cleanser, appears to be the best answer. The frequent use of the toothbrush will be necessary for the massage of the gums to increase capillary circulation.

Because of the scarcity of water, a dentifrice should be used which will dissolve in the saliva. A 50-50 percent salt-soda mixture can be recommended. The advantages of this chemical mixture are that it is dry and lightweight; little is required for each individual use; it dissolves mucousbacterial plaques; and, before dissolving in the saliva, it acts as a mild abrasive. After the use of this dentifrice, no rinsing is necessary and the crushed debris from the mouth can be expectorated.

It is planned to explore the possibility of using airjet instead of brush cleaning. It is expected that, in every space vehicle and also in the Moon Base, there will be compressed air with about 100 psi available. If this technique will satisfy hygiene requirements, it will save considerable weight.

THERAPEUTICAL TECHNIQUES

It must be expected that, in spite of thorough clinical dental examination and precise hygiene measures, not all toothache can be prevented during a lunar mission. It was of great concern that, in cases of emergencies, a simple technique be used which

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does not require extensive armamentarium and excessive skill and training for tooth extraction. The simplest procedure seems to be to apply intramuscular anesthesia into the gum and, with the aid of a small airturbine drill, open the nerve canal and extract the nerve. It is quite simple to maintain drainage during the whole mission without danger of infection.

It will require quite extensive studies to determine the minimum instrumentarium and drug supply for the lunar missions. Should one consider an appendectomy or similar acute emergency? If so, it is obvious that a limit must be established, because hospital instruments are heavy and bulky. On the other hand, 3 to 4 days is the shortest time for the round trip between earth and moon, and this may be too long to save a stricken crew member.

How far should one go in taking calculated risks?

Section 7

DETERMINATION OF BASIC PSYCHOLOGICAL PARAMETERS FOR CREW SELECTION

The desirability of sending highly coordinated, motivated teams of specialists into space for extended periods will be noted very soon in the space-flight program. In order to keep human operator parameters on a developmental par with machine technology, it is necessary to anticipate in advance the practical uses of both potential and existing hardware. Only then can human research, training, and indoctrination methods be applied to produce results linear to machine advances.

Initial screening of Moon Base candidates will probably be overly rigid, but volunteer numbers should more than make up for the expected attrition rate. Broadly envisioned, each candi-

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date will be realistically and highly motivated for the task, possessed of superior physical and intellectual abilities, able to demonstrate control and effectiveness under stress, and possessed of the necessary technical skills.

Psychological parameters for crew selection will follow procedures such as:

1. Psychiatric examination, with concomitant neurologic and clinical psychologic examinations.
 - a. Electroencephalographic recordings for base-line studies.
 - b. Follow-up research and clinical neurology.
2. Tests comparable to the present pilot-selection examinations, supplemented by personality inventories and determination of psychophysiology and performance parameters.

On the group level, attention must be paid to the danger of irritation resulting from constant personal proximity and possible boredom. It is possible that some Navy submarine experiences have provided alleviatory techniques applicable to this problem, but ground-based space environment simulators should provide more exacting and reliable procedures. The results of these studies will add greatly to measurement of team effectiveness on team selection, team training, cross-training, member replacement, and assembly.

One of the most interesting possibilities in the operation of a closed ecosystem for long temporal periods would be in the observation of any emergent sub-groups within the crew complement. The appearance of such units could result in a performance decrement if, for example, the sub-unit were at odds with the intents of the mission. The lunar environment simulator would provide an excellent means for investigating such possibilities.

Additional individual problems may arise in the use of the space suit. The disorienting effects of sub-gravity, the dichotomy of light and dark, and various features of the suit itself may give rise to undesirable emotional reactions.

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Every effort should be made in developing the various reliable and valid testing and training procedures now available. Research in the proposed Moon Base simulator should provide newer and more efficient means to accomplish these ends.

Section 8

MOON BASE TRAINING SCHEME FOR FUTURE CREW MEMBERS

The focus of interest in the training of space crews is the minuscule allowable error in equipment operator functioning. Such a required level of excellence demands indoctrination in every conceivable parameter of ecosystem functioning, a feat which is impossible at this stage of the space-flight program. Important in the preparation of each human for early missions will be the condition that he "make up the difference" for phenomena anticipated and prepared for, and those not recognized or entirely unknown.

The selected and voluntary crew will enter into the Moon Base prototype and lunar environment simulator with the conviction that it is "just another test on earth." But after a few weeks, during which every sensory perception would indicate a lunar environment, the illusion will become more and more manifest until, depending on individual susceptibility, the auto-suggestion is more or less complete and the crew will believe themselves to be on the moon. Such an illusion can be greatly enhanced with post-hypnotic suggestion. There are numerous such experiences reported in the literature. To mention only one: many pilot students who have been in a Link trainer for prolonged time, when the instructor programs into the instru-

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ments crash conditions, will "bail out," and it is known that some were injured.

The conditions which the operator will face in real space environment are not *exactly* those which one will encounter in our highly developed simulator. Consequently, it is expected that there will be adjustments necessary even after thorough indoctrination and training, but it is expected that the elasticity and the adaptability of the human organism will be able to bridge these gaps.

The principle areas of training can be subdivided into three parts: (1) survival indoctrination and habituation, (2) operation and maintenance of all equipment systems and sub-systems, (3) navigation and communications.

Preceded by comprehensive class indoctrination, these areas can be applied effectively in the ground-based simulator and later the navigational skills can be perfected in operational craft. The detailed outlining and special training and indoctrination technique will lean partially on upgraded flight requirement.

The situation becomes less simple as candidates begin to show fairly comparable performance levels under equally demanding stresses. It is then up to the tester to reveal, by even more punishing testing-training, the disabilities which could compromise a mission.

Without the use of test situations to rule out candidates, we may establish certain criteria for the elimination of personnel where at least these six personality characteristics fail to emerge:

1. Uncritical appraisal of those in the work situation about him, based not on moralistic concepts but on realistic evaluation of peers and their level of proficiency, as seen in the light of their varied personal histories.
2. An intellectual orientation of outlook which can be partially shelved in favor of temporary conditions requiring deep emotional empathy with a fellow, for the good of his mental health.
3. Skill in observing the dynamics of the cabin social field as it relates to crew proficiency. This criterion implies a high de-

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gree of insight and honesty, especially in evaluating emergent group sub-systems and their influence on total system performance.

4. An attitude which expresses itself emotionally in a lively, pleasant, and stimulating source of confidence to the other members of the expedition, even in the face of deprivation.
5. Use of personal mental and physical resources as a source of pleasant reverie and entertaining self-stimulation.
6. Ability to tolerate a broad latitude of libido influence and satisfaction which may demonstrate itself in a symbolic and/or physical manner — both in himself and the other personnel. (This factor will be dealt with later.)

Most of these traits can be discovered or brought out in trainees through testing of a written nature, an interview situation, or observation of the carefully manipulated instructional program. Motivation on the part of the candidate, although thought to be genuine, must not be accepted without close scrutiny. For example, a good deal of such fervor may vanish upon reaching of some personal goal far less than what the planners of the mission consider minimal to its success.

The Moon Base must be operated by the chosen personnel for varying periods, probably from 1 week up to 6 months. The question of utilizing different character types based on the length of the proposed mission seems optimistic in the light of possible failure of the supply, replacement, and return vehicle. A crew chosen for a week's operation may end up existing in the tiny dome for several times the originally planned period. It is believed that each crew must be chosen as though it were to operate for the longest projected time, which, indeed, it could.

One method of elimination from the training program might be to establish chamber tests for candidates who are informed of a 1-week stay, only to have this period protracted, under varying degrees of deprivation, to a much longer time — or until crew performance becomes less than minimal.

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It would seem that the ultimate criterion for the choice of one crew over another would be over-all ability to succeed in the face of a simulated Moon Base environment. To facilitate the assembly of optimal crews, careful placing of compatible trainees in three-person units is suggested. These units can be shuffled experimentally to achieve the highest end output. In this respect, the sex ratio of the crews is of little moment; one crew complement might differ from that of another equally acceptable unit. The functioning of one crew may involve idiosyncracies peculiar to that group only; what is important is group performance. Research should provide the answer to questions of crew sex ratio.

LIBIDO FACTORS DUE TO TIME BREAKS

Libido factors in the operation of a closed ecosystem will pose problems, especially in crew selection. It is difficult to say whether such influences will be positive or negative until they are seen affecting a given crew. The satisfaction of sexual and related drives takes on liability in terms of crew proficiency only when such satisfactions do not psychologically allow proper monitoring of the system. We would have to be familiar with the manner of sex satisfaction and expression of each human component in a crew. Social interaction within the vehicle would then suffer or gain, as measured by crew performance, according to the degree of individual and group acceptance of sexual behaviorisms.

The symbolic expression of sexual tendencies can be detrimental to the mission when:

1. By their overt nature, they impair the close interaction of the human and his machine system, with a corresponding proficiency attenuation.
2. By their distractive characters, they capture too much attention from one or more of the crew.
3. Their existence may draw from mental energy and attention-giving functions, thereby reducing receptivity to more important external and internal stimuli.

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Discovering the manner of libido expression on the physical and psychological level of all candidates for lengthier space missions is a prime requirement. The sudden or gradual emergence of an objectionable trait or response while engaged in a flight or operation might lead to disaster in terms of proficiency.

Psychological tests, interviews, and observation of the history and the present performance of a candidate under simulated Moon Base conditions opens the way for insight into recording of the basic tendencies in each individual's libido satisfaction. Such information could be utilized in the selection of crews, with a greater chance for optimal social relations and corresponding completion of the mission.

Emergence of the Libido under Short-Term Highly Rigorous Missions

The emergence of the libido in the case of a mission of extremely short duration can be said to be a problem that will not aggravate the first brief space flights. One does not think of the libido factors operating among crew members in an inter-continental bomber. The members of such groups simply do not have the time or energy for such endeavors, at least as expressed overtly. In addition, these missions do not occupy too long a time, nor will the first orbital or circumlunar missions.

Perhaps, as space travel becomes much more sophisticated, the sex drive will manifest itself in other than revery, symbolism, or slight discomfort. But we assume that this will be most observable in passenger-type travelers. The crew itself may be much too occupied with the requirements of the vehicle to be affected, if we are to judge by airline flights today. In addition, their training and personal interest in seeing the completion of the journey should cause them, to a great extent, to suppress or re-channel such stimuli.

Emergence of the Libido under Rigorous-to-Relaxed Long-Term Missions

A space mission consisting of cycles of duty and rest would probably result in the emergence of considerable sex drive over

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a length of time. Ideally, this drive would be gratified on "off-duty" time, barring emergency, in which "off-duty" would be a myth. The methods of gratification remain unimportant insofar as they cause no compromise of the mission. Selection of crews, preceded by psychological testing and other methods to determine the manner of outlet, would help eliminate possibilities of divergent sub-groups appearing while performing the mission.

The problem of actual orgasmic release will be treated by the trainers in a proper and scientific fashion. This would be educative in two ways: it would breed greater tolerance for observed actions of peers, and would bring latitude to the instructee's knowledge. If, however, the mission is such that requires the complete attention of all personnel, controls might have to be individually employed to prevent suppressed sex drives from damaging performance. The nature of any control would relate to the peculiarities of the group, sub-groups, and separate individuals. Probably the best depressant and the easiest to administer would be a mutually increased desire to see the mission through with the best performance possible. Others could be locally applied numbing agents, drugs, etc.

Emergence of the Libido under Long-Term Rigorous Missions

The fatigue accompanying individual acts in long-duration periods is more complicated than the fatigue involved in short-term flights, because of the added cumulative effect. Libido emergence, according to the literature, does not come until there is a sufficient period of relatively stress-free relaxation. Even then, cumulative fatigue arising from earlier stress is a further deterrent to sexual tendencies until it is reduced. If some long-term operations are conducted under very demanding conditions over the entire length of the mission, we might expect more difficulty from fatigue resulting from stress, boredom, repetition, etc., than from non-existent or transient libido influences.

Nevertheless, sexual energy may seek to manifest itself in some or all of the crew members at any point along the continuum of lengthy missions, no matter how strenuous they are observed

to be. The relief of such drives would be substantially no different than the method used on a long mission of less demanding nature. In the case of physical gratification, a problem might arise in finding the opportunity for whatever release device is to be used without weakening the function of some part of the system. Absorbing fantasy, channeling of thoughts resulting in decreased proficiency, and other symptoms of the libido drive would have to be curbed by training and desire to complete the mission successfully.

Section 9

SPACE PSYCHOPHARMACOLOGY

It has been established that, for human space flight, medication will be inevitable in order to extend the tolerance toward environmental and psychological stresses. The general pattern of research in the field of psychopharmacology did not specifically include the effects of certain drugs on the stress parameters which are prevalent in astronautics. Neither was the focus of interest on the possible and probable changes of the clinical findings as they would occur if the psychomimetic drugs were applied under multiple environmental stresses.

It is expected, after the excitement of the adventure of exploring the moon has diminished, that a reaction in the form of depression may overcome some of the crew members. Since, for the optimal functioning of the lunar society, everybody's *joie de vivre* is a prerequisite, the proper administration of hallucinogens resulting in euphoria is well indicated. A slight hypoxia is known to add to this effect.

One of the more valuable and interesting experiments will be when, according to the monitoring psychiatrist, one of the

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crew members has reached the psychological breaking point. With all available means — administration of drugs, persuasion by family members through the communication system, etc. — he should be kept physically and mentally sane for four more days. The experience and the results will be invaluable for future operations, because it will take four days to rescue a crew member from the moon in case of a nervous breakdown or if — as mentioned before — a sudden medical operation becomes necessary.

GLOSSARY

- Å** - Angstrom, 10^{-8} cm.
- Ambient** - surrounding.
- Armamentarium** - equipment.
- Attenuate** - to reduce in intensity.
- Autosuggestion** - suggestion arising from the individual himself.
- Beta particles (β)** - electrons emitted from atomic nuclei in radioactive decay.
- Biocatalyst** - collective name for enzymes, vitamins, and hormones.
- Bit information** - the smallest discrete unit of information.
- Bremsstrahlung** - "braking radiation," soft gamma ray given off by the dissipation of the energy of an electron during the attenuation in matter.
- Caries** - decay, as of bone or teeth.
- Chloroplasts** - small particles in plant cell; contain chlorophyll.
- Cis-lunar** - space this side of the moon.
- Ecology** - the science concerned with the relations of living organisms and their environments.
- Ecosystem** - independent living environment.
- Electrocardiogram (EKG)** - a graphic record of the heart's action traced by an electrocardiograph.
- Electroencephalogram (EEG)** - the graphical recording of the electrical currents produced by the brain.
- Euphoria** - increased feel of well-being.
- Explosive decompression** - effect of a sudden drop of the ambient pressure on living organisms.
- Galvanic skin response (GSR)** - psychologically influenced electrical resistance of the human skin.
- Hallucinogens** - drugs causing hallucinations.
- Hygrometer** - an instrument to determine air humidity.
- Ionizing radiation** - photons, electrons, or nuclear particles with enough energy to remove one or more electrons from an atom.
- Isodose** - contour of points on a surface having identical radiation dose.
- Kev** - Kilo (1000) electron volts of energy.
- Kinesiology** - the feel or sensation of the position of various parts of the body.
- Lambert** - a unit of brightness equal to the average brightness of a surface emitting or reflecting 1 lumen per cm^2 .
- Libido** - used, in this book, in its usual sense of sexual desire.
- Lumen** - the luminous flux in unit solid angle from a uniform source of 1 candle power. Brightness is measured in lumens/ cm^2 /steradian, or in candles/ cm^2 . 1 lumen = $1/4\pi$ (candle power).
- Mastication** - act of chewing food.
- Melanin** - the dark pigment in the body of man and certain animals, as that occurring in the hair, epidermis of colored races, etc., or one produced in certain diseases.
- Millibar** - $1/1000$ bar.
- Millilambert** - $1/1000$ lambert.

GLOSSARY

- Multiplexed** - more than one channel of information transmitted on one frequency.
- Muscular dystrophy** - degradation of skeletal muscles.
- Parameters** - considerations relevant to a subject.
- Partial pressure** - the pressure of one particular gas in a gas mixture.
- Pathological** - referring to abnormal and diseased conditions in organisms.
- Photo-assimilation** - utilization of chemical compounds, carbon dioxide in particular, by green plants.
- Photolysis** - the separation of water into hydrogen and oxygen, induced by photonic radiations such as light.
- Photons** - a quantum of radiant energy.
- Phyto-organism** - plant.
- Polymers** - materials made of long chain molecules such as polyethylene, built by chemically interlocking short molecules.
- Psychomimetic** - drug action bringing about psychological states observed by abnormal mental conditions.
- Psychomotor** - related or referring to the motor effects of mental (cerebral) processes.
- Psychopharmacology** - the study of the effects of drugs on behavior.
- Psychophysiological** - the branch of experimental psychology which investigates the functional and quantitative relations between physical stimuli and sensory events.
- Psychosomatic** - the correlation of psychological phenomena, normal, abnormal, or pathological, with somatic or bodily conditions or variations.
- Quantum conversion** - in this book, conversion of electromagnetic radiative energy into biochemical energy.
- Radicals** - a group of atoms which remains intact throughout many chemical reactions and which exhibits a constant valence in all compounds in which it is present.
- Radiolysis** - the decomposition of water into hydrogen and oxygen by nuclear radiation.
- Roentgen** - unit of x- or γ radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying 1 electrostatic unit of quantity of either sign.
- SNAP-III** - electrical battery using the heat production of nuclear radiation.
- Social sub-group** - a numerically smaller group within the larger social structure; its formation may be thought of as due to low cohesiveness within the larger unit.
- Sub-gravitational** - gravitational acceleration of a lesser value than that on the earth (1 g).
- Sympathetic nervous system** - ties psychological events with physiological actions.
- Thermoconductivity** - conduction of heat.
- Transceiver** - receiver-transmitter combination.
- Transducer** - a device which changes energy from one form to another.
- Trans-lunar** - beyond the moon.

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